Proceedings of the 13th International Conference on Disability, Virtual Reality and Associated Technologies (ICDVRAT 2021)

UNIVERSIDADE
LUSÓFONA

The 13th International Conference on

Disability, Virtual Reality and Associated Technologies

Proceedings

Edited by:

Pedro Gamito
David Brown
Sebastian Koenig

September 8th to 10th, 2021

Serpa, Portugal, and online

UNIVERSIDADE
LUSÓFONA

ICDVRAT 2021

The papers appearing in this book comprise the proceedings of the 13th International Conference on Disability, Virtual Reality and Associated Technologies, held between the 8th and 10nd of September 2021 in Serpa, Portugal and online on the Crowdcast platform. The papers presented reflect the authors' opinions and are published as presented and without change (formatting and minor editing excepted). Their inclusion in this publication does not necessarily constitute endorsement by the editors and ICDVRAT.

Please use the following format to cite material from these Proceedings:

> Author, AB, Author, CD, and Author, EF (2021), Title of paper, *Proc. 13th Intl Conf. on Disability, Virtual Reality and Assoc. Technologies*, P Gamito, D Brown, and S Koenig (Eds), pp. *n–m*, Serpa, Portugal, 8–10 Sept. 2021.

Proceedings reference number: TBD

Published by

Universidade Lusófona de Humanidades e Tecnologias, Portugal

For information, contact:

Campo Grande 376, 1749-024 Lisboa, Portugal
Phone: +351 21 751 5500

Email: pedro.gamito@ulusofona.pt Web: http://icdvrat2020.ulusofona.pt/

Conference Schedule at a glance

Wednesday, 8 September 2021

14:00	Conference Opens
14:30 – 15:00	Opening Session
15:00 – 16:00	Keynote: Skip Rizzo "The Evolution of Virtual Humans in Clinical Virtual Reality and Beyond!"
16:00 – 16:45	Session I: Physical and Motor Rehab Studies
16:45	Coffee
17:15 – 18:15	Session II: Physical and Motor Rehab Studies

Thursday, 9 September 2021

09:30 – 10:30	Session III: Cognitive Assessment and Rehabilitation
10:30 – 11:30	Session IV: Synthetic Agents
11:30	Coffee
12:00 – 13:15	Session V: VR and Psycho-Medical Applications
13:15	Lunch
14:45 – 16:15	Session VI: Cognitive Assessment and Rehabilitation
16:15	Coffee
16:45 – 17:45	Session VII: Cognitive Assessment and Rehabilitation
17:45 – 18:45	Keynote: Pierre-Paul Vidal "If the style is the man himself, how to quantify it?"
18:45 – 19:45	Steering Committee

Friday, 10 September 2021

09:30 – 11:15	Session VIII: VR and Psycho-Medical Applications
11:15 – 12:00	Poster Session
12:30	Coffee
12:30 – 13:30	Keynote: Tony Brooks "(Working towards) Probably the best (re)habilitation complex in the world"
13:30 – 14:00	Prize Session
14:00 – 14:15	Closing Remarks
14:15 – 15:00	Light Lunch (for in-person attendees)

Contents

Session I Physical and Motor Rehabilitation Studies

Session II Cognitive Assessment and Rehabilitation

Session III Synthetic Agents

Session IV VR and Psycho-Medical Applications

Short Papers

Conference Organisation

Conference General Chairs

Pedro Gamito, Universidade Lusófona de Humanidades e Tecnologias, Portugal

David Brown, Nottingham Trent University, UK

Programme Committee Chair

Sebastian Koenig, Katana Simulations Pty Ltd, Adelaide, Australia

International Programme Committee

Mohammad Al-Amri, University of Cardiff, UK
Philippe Archambault, McGill University, Canada
Robert Astur, University of Connecticut, USA
Sergi Bermúdez i Badia, Universidade da Madeira, Portugal
Melanie Banina, McGill University, Canada
Christos Bouras, University of Patras, Greece
Philip Breedon, Nottingham Trent University, UK
Jane Broida, Metropolitan State University of Denver, USA
Tony Brooks, Aalborg Universitet Esbjerg, Denmark
David Brown, Nottingham Trent University, UK
Mónica Cameirão, Madeira Interactive Technologies Institute, Portugal
Georgina Cárdenas-López, National Autonomous University of Mexico, México
Darryl Charles, University of Ulster, Northern Ireland
Imre Cikajlo, Univerzitetni Rehabilitacijski Inštitut, Slovenia
Sue Cobb, University of Nottingham, UK
Bonnie Connor, Neuropsychologist, California, USA
Alessia Coppi, Swiss Federal University for Vocational Education and Training, Switzerland
Rosa Maria E. Moreira da Costa, Universidade o Estado do Rio de Janeiro, Brazil
Jean Detheux, Vudici, Canada
Judith Deutsch, Rutgers University, New Jersey, USA
Andreas Duenser, Commonwealth Scientific and Industrial Research Organisation, Australia
Michal Elboim Gabyzon, University of Haifa, Israel
Michael Gaebler, Max-Planck Institute for Human Cognitive and Brain Sciences, Germany
William Farr, Sussex Community National Health Service Trust, UK
Gerard Fluet, Rutgers University, New Jersey, USA
Joyce Fung, McGill University, Canada
Pedro Gamito, Universidade Lusófona de Humanidades e Tecnologias, Portugal
Jose-Antonio Gil-Gomez, Universitat Politècnica de València, Spain
Dido Green, Oxford Brookes University, UK
Bruno Herbelin, L'Ecole Polytechnique Fédérale de Lausanne, Switzerland
Simon Hoermann, University of Otago, New Zealand
Sarah Howes, University of Ulster, Northern Ireland
Naomi Josman, University of Haifa, Israel
Emily Keshner, Temple University, Philadelphia, USA
Rachel Kizony, University of Haifa, Israel
Evelyne Klinger, ESIEA, Laval, France
Felix Klotzsche, Max-Planck Institute for Human Cognitive and Brain Sciences, Germany
Sebastian Koenig, Katana Simulations Pty Ltd, Adelaide, Australia
Mel Krokos, University of Portsmouth, UK
Sarah Kruger, Walter Reed National Military Medical Center, Bethesda, MD, USA
Tomohiro Kuroda, Kyoto University Hospital, Japan
Orly Lahav, Tel Aviv University, Israel
Anouk Lamontagne, McGill University, Canada

Belinda Lange, Flinders University, Adelaide, Australia
Mindy Levin, McGill University, Canada
Roberto Lloréns, Labhuman-Universitat Politècnica de València, Spain
Tobias Loetscher, University of South Australia, Australia
Liliane S Machado, Federal University of Paraíba, Brazil
Ian Male, Sussex Community National Health Service Trust, UK
Rachel McCrindle, University of Reading, UK
Suzanne McDonough, University of Ulster, Northern Ireland
Alma Merians, Rutgers University, New Jersey, USA
Henry Moller, University of Toronto, Canada
Francesca Morganti, University of Bergamo, Italy
Alessio Murgia, University Medical Center Groningen, Netherlands
Luciana Nedel, Federal University of Rio Grande do Sul, Brazil
Nigel Newbutt, University of the West of England, Bristol, UK
Jorge Oliveira, Universidade Lusófona de Humanidades e Tecnologias, Portugal
Lena Pareto, University West, Trollhättan, Sweden
Wendy Powell, University of Portsmouth, UK
Albert (Skip) Rizzo, University of Southern California, USA
Paul Sharkey, University of Reading, UK
Cecília Sik Lányi, University of Pannonia, Hungary
Teresa Souto, Universidade Lusófona de Humanidades e Tecnologias, Portugal
P J Standen, University of Nottingham, UK
Sandeep Subramanian, McGill University, Canada
Isabelle Viaud-Delmon, CNRS, Paris
Patrice L (Tamar) Weiss, University of Haifa, Israel
Peter Wilson, Australian Catholic University, Australia

Conference Local Organising Committee

Pedro Gamito, Universidade Lusófona de Humanidades e Tecnologias, Portugal

ICDVRAT Conference Steering Committee

Paul Sharkey, University of Reading, UK (Chair)
Jurgen Broeren, Göteborg University, Sweden
Tony Brooks, Aalborg Universitet Esbjerg, Denmark
David Brown, Nottingham Trent University, UK
Evelyne Klinger, ESIEA, Laval, France
Sebastian Koenig, Katana Simulations Pty Ltd, Adelaide, Australia
Lena Pareto, University West, Trollhättan, Sweden
Albert (Skip) Rizzo, University of Southern California, USA
Martin Rydmark, Göteborg University, Sweden
Jaime Sánchez, Universidad de Chile, Chile
Cecília Sik Lányi, University of Veszprém, Hungary
P J Standen, University of Nottingham, UK
Patrice L (Tamar) Weiss, University of Haifa, Israel

Introduction

The 13th International Conference on Disability, Virtual Reality and Associated Technologies (ICDVRAT 2021) provides a forum for international experts, researchers, clinicians and user groups to present, review, and discuss how advances in the general areas of Virtual Reality and Interactive Technologies can be used to assist people with Disability.

ICDVRAT is now in its 25th year, with biennial conferences in the series previously held in Maidenhead, UK (1996), Skövde, Sweden (1998), Alghero, Sardinia, Italy (2000), Veszprém, Hungary (2002), Oxford, UK (2004), Esbjerg, Denmark (2006), Maia & Porto, Portugal (2010), Viña del Mar/Valparaíso, Chile (2010), Laval, France (2012), Gothenburg, Sweden (2014), Los Angeles, USA (2016), and Nottingham, United Kingdom in 2018. Due to the global COVID-19 pandemic, ICDVRAT 2020 was delayed to 2021 and was changed to the series' first ever hybrid event with more than half of all attendees watching and presenting their research online.

After two rounds of peer reviews in 2020 and 2021, the International Programme Committee selected 37 Full Papers for presentation at the conference, divided into 7 plenary sessions and four broad topic categories: Physical and Motor Rehabilitation Studies, Cognitive Assessment and Rehabilitation, Synthetic Agents, and VR and Psycho-Medical Applications. 11 of the Full Papers were accepted into a special issue of the Virtual Reality journal published by Springer and are included as 2-page short abstracts in these proceedings. An additional 14 Short Papers were accepted which are presented during the Short Paper session and as posters throughout the conference. The conference is held over three days between September 8th and 10th at the Musibéria in Serpa, Portugal, as well as online at https://www.crowdcast.io/e/icdvrat2021

ICDVRAT 2021 is proud to host three invited keynote speakers. Albert "Skip" Rizzo will present the opening keynote addressing the history and current state-of-the-art in Virtual Human Technology for clinical use. Pierre-Paul Vidal and Tony Brooks will deliver their invited keynote presentations on conference days two and three respectively.

The video recordings of each conference session can be found on the Crowdcast platform, using the conference link above. The Conference Proceedings will be submitted to a publisher or citation database and made available once this process is completed.

Acknowledgements

The Conference Chairs would like to thank the ICDVRAT Programme and Steering Committees for their commitment to the review and planning process, all authors who have submitted to the conference, the Organization Committee, Conference Sponsors, and the students who commit their time to make the conference a success.

On behalf of ICDVRAT 2021, we welcome all delegates who have travelled to Serpa or are joining us online to the Conference and sincerely hope that delegates find the conference to be an enjoyable and insightful event.

Pedro Gamito, David Brown and Sebastian Koenig

Conference Sponsors

The main sponsor of ICDVRAT 2021 is:

Universidade Lusófona de Humanidades e Tecnologias, Portugal

The organisers wish to express their gratitude to the other major sponsors of the conference:

International Society for Virtual Rehabilitation

Katana Simulations Pty Ltd

Musibéria

Nottingham Trent University

HEI-Lab Digital Human-Environment Interaction Lab

FUEL Bar

Município de Serpa

Additional help in publicising the conference has been gratefully received from the ISVR and VRPSYCH-L facebook pages, amongst many others.

Conference Prizes

The conference awards two prizes: The Best Paper Award and The Standen Award for Early Career Researchers.

The International Society for Virtual Rehabilitation (www.isvr.org) is the 2021 sponsor for The Best Full Paper Award.

Katana Simulations Pty Ltd is the 2021 sponsor for The Standen Award.

Early Career papers are papers where a student, doctoral student or doctoral candidate is affirmed to be the primary author and where the paper is presented by that student at the conference. These papers are identified prior to the conference on submission of the final paper.

The 2021 Best Paper Award was awarded to:

Normative Data for a Next Generation Virtual Classroom for Attention Assessment in Children with ADHD and Beyond!, **Albert "Skip" Rizzo, J Chen, J Wang, A Ma, CY Chang, J Turnbull, C Shao**

Runner up for the 2021 Best Paper Award:

Putting into a female body: the feasibility of 360° video-based virtual reality to induce the body swap illusion, **Sara Ventura, G Cardenas, M Miragall, G Riva, R Baños**

The 2021 Standen Award for Early Career Researchers was awarded to:

Assessment of spatial navigation in multiple sclerosis and antiNMDA receptor encephalitis using virtual environments, **Sophia Rekers, G Cooper, J Heine, S Krohn, H Prüss, F Paul, C Finke**

Runners up for the 2021 Standen Award for Early Career Researchers:

Evaluation of a virtual reality tandem-bike exergame for rehabilitation, **Emil Hoeg, J Bruun-Pedersen, S Cheary, L Andersen, R Paisa, S Serafin, B Lange**

Predicting motor behavior: an EEG signal processing pipeline to detect brain states with potential therapeutic relevance for VR-based neurorehabilitation, **Eric McDermott, J Metsomaa, P Belardinelli, M Grisse-Wentrup, U Ziemann, C Zrenner**

Keynote: Prof. Albert "Skip" Rizzo

The Evolution of Virtual Humans in Clinical Virtual Reality and Beyond!

Albert Rizzo

University of Southern California, California, USA

BIO-SKETCH

Albert "Skip" Rizzo is a clinical psychologist and Director of Medical Virtual Reality at the University of Southern California Institute for Creative Technologies. He is also a Research Professor with the USC Dept. of Psychiatry and at the USC Davis School of Gerontology. His career began as a clinician providing rehabilitative services for persons with traumatic brain injuries and stroke. Over the last 25 years, Skip has conducted research on the design, development and evaluation of Virtual Reality systems targeting the areas of clinical assessment, treatment and rehabilitation across the domains of psychological, cognitive and motor functioning in both healthy and clinical populations. This work has focused on PTSD, TBI, Autism, ADHD, Alzheimer's disease, stroke and other clinical conditions. Some of his recent work has involved the creation of artificially intelligent virtual human (VH) patients that novice clinicians can use to practice skills required for challenging diagnostic interviews and for creating online virtual human healthcare guides, and clinical interviewers with automated sensing of facial, gestural, and vocal behaviors useful for inferring the state of the user interacting with these virtual human entities. In spite of the diversity of these clinical R&D areas, the common thread that drives all of his work with digital technologies involves the study of how interactive and immersive Virtual Reality simulations can be usefully applied to address human healthcare needs beyond what is possible with traditional 20th Century tools and methods. To view some videos of this work, please visit this YouTube channel: https://www.youtube.com/user/AlbertSkipRizzo/videos

Keynote: Prof. Pierre-Paul Vidal

If the style is the man himself, how to quantify it?

Pierre-Paul Vidal

Université Paris Descartes, France

BIO-SKETCH

Pierre-Paul Vidal began his studies in Medicine and Human Biology at the University of Medicine of Pitié Salpétrière. These studies were completed with a medical thesis in 1978 and a research degree in human biology in 1980. After a DEA in Neuroscience in 1981, he started a PhD thesis in science in 1982 as a DGRST fellow which was completed in 1986. Pierre Paul Vidal became a member of the CNRS Laboratory of Occupational Physiology during his studies as an assistant in the Physiology Department where he began his career as a researcher and physician. He joined the CNRS in 1980 as a research associate. Pierre-Paul Vidal was appointed research fellow in 1984 and research director in 1990. He is currently Director of Research of exceptional class Emeritus. During his training he did several internships abroad: one year at the Aviation Medical Research Unit, (N.A.T.O. Fellowship,) at Mc Gill University, Montreal, 1978; three and a half years of post-doc, first at the Laboratoire de Neurobiologie de l'Ecole Normale Supérieure (1983) and then at the Department of Physiology and Biophysics, at N.Y.U. Medical School, for two and a half years. During his professional career he had the privilege, thanks to the CNRS, to create and head three research laboratories in integrative neuroscience: the Laboratory of Neurobiology of Sensorimotor Networks in 1997, the Center for the Study of Sensorimotricity in 1990 and the " Cognition and Action Group " (UMR 8257 MD) first and only UMR MD (Ministry of Defense) in 2014. He is co-founder of the Borelli Center in 2020 directed by Pr Nicolas Vayatis. He has published 186 articles to date on sensorimotor control. Pierre-Paul Vidal is a full professor at Hangzhou Dianzi University, Hangzhou, China and an associate professor at the Fra Gemelli Medical University, Università Cattolica del S. Cuore and. He directs the BME Master's program, which started at HDU Hangzhou (China) in 2016. He is also President of the expert committee for biomedical promotion of the INSB of CNRS, CNRS representative to the Board of the Biomedicine Agency, Director of the Platform for the Study of Sensorimotricity of the Saints Pères René Descartes University, and Member of the Scientific Council of the IRME. Finally, Pierre-Paul Vidal is associate editor of three scientific journals (Frontiers in Neurology, Sensors and Experimental Brain Research

Keynote: Dr. Anthony Brooks

(Working towards) Probably the best (re)habilitation complex in the world

Anthony Brooks

Aalborg University, Denmark

BIO-SKETCH

Dr. Anthony Brooks is Associate Professor at Aalborg University, Denmark where he has been director/founder of the 'SensoramaLab" and a founding team-member of the 'Medialogy education' (Bsc, Msc, PhD) and as section leader, lecturer, coordinator, supervisor, and study board member. He is also lecturer, supervisor and coordinator on the 'Art and Technology education' (BA) and study board member. He has been active working for the European Commission as project evaluator, rapporteur, and expert reviewer for approximately fifteen years ongoing. His research has been catalyst for numerous externally funded International, European and National projects as well as a media art/serious-games industry start-up company, and a family of patents resulting from his evolved method and prototypes. Cross-disciplinary emergent models have also resulted. Originating from Wales, born into a family with disabled members, at an early age he 'invented' alternative solutions for adaptive accessibility and creative 'control' of stimuli. In the 1980s he created bespoke instruments and volumetric invisible sensing systems for unencumbered gesture-control of digital media to stimulate meaningful causal interactions that could be tailored to individuals, their needs, preferences and desires alongside the outcome goals of artists, facilitators, therapists, educators etc. As first artist in residence at the Centre for Advanced Visualisation and Interactivity (CAVI) at Aarhus University, Denmark at the end of 1990s, he originated the ZOOM emergent model (Zone of Optimized Motivation) for in-action intervention and on-action analysis and assessment /refinement across fields of healthcare and learning. He has approximately 200 publications. He is acknowledged as a third culture thinker and "world pioneer in digital media and its use with the disabled community" where creative artistic expression acts as catalyst for new opportunities in practise. His artistic work has been featured at major events around the world, including two Olympics/Paralympics (Atlanta 1996; Sydney 2000), numerous European Cultural capital showcases, and also at more underground events such as the Danish NeWave in New York City 1999. His interactive art installations have been exhibited at numerous renown Museums of Modern Art. Tony has been plenary keynote speaker at approximately fifteen international events and he is Danish representative for UNESCO's International Federation for Information Processing Technical committee on "Entertainment Computing". Under the European Alliance for Innovation (EAI) he has steered the International Conference ArtsIT since 2009.

Virtual Reality and Rehabilitation: Review of Reviews

Noël Keijsers[1], Pauline Aärts[1], Laurent Grisoni[2], Kristina Műller[3], Shaun Wellburn[4], Denis Martin[4], Dido Green[5,6,7]

[1]Saint Martinsclinic, Nijmegen, NETHERLANDS

[2]Université de Lille - Sciences et Technologies, Lille, FRANCE

[3]St. Mauritius Therapieklinik, Dusseldorf, GERMANY

[4]Teesside University, Middlesborough, UNITED KINGDOM

[5]Royal Free London NHS Foundation Trust, UNITED KINGDOM

[6]Division of Clinical Sciences, Brunel University London, UNITED KINGDOM

[7]School of Health and Welfare, Jönköping University, Jönköping, SWEDEN

[5]*Dido.green@nhs.net* [6]www.royalfree.nhs.uk/ [7]www.brunel.ac.uk/people/dido-greeen

ABSTRACT

***Objective**:* Virtual reality (VR) provides an environment in which users may immerse themselves as if real, providing multiple opportunities for technologies and gaming solutions to assist rehabilitation. While multiple studies are emerging reflecting the increased use of VR in rehabilitation, this review aims to pull together reviews of VR to consider the evidence across contexts of rehabilitation practice. Corresponding to the challenge themes of the VR4REHAB InteReg project the review focused on: lower and upper limb function; pain; memory impairments and treatment adherence.

***Design**:* Systemised Review of Reviews

Materials and Methods: The Participant Intervention Comparison Outcome Framework was used to identify core search terms of VR and synonyms or related areas of practice (e.g. OR augmented reality) AND rehabilitation terms (e.g. Rehab* OR Therap*) AND with topic specific terms (e.g. pain OR physical suffering). Databases searched included Cochrane Library and PubMed with a second search including CINAHL, AMED, PsychInfo and IEEE Explore. Key words related to aims of study. Two interns conducted searches and extracted data from all articles. Findings were categorised based on the subdomains of body function, activities and participation from the International Classification of Functioning, Disability and Health.

Results: From a total of 763 hits, 199 reviews were identified. Of the 19 reviews of VR use for the lower limb and 52 of the upper limb, the majority focused on the stroke population. While insufficient good quality evidence to reach conclusions generally, evidence supports beneficial effects on gait and balance in the elderly and fewer for individuals with multiple sclerosis, traumatic brain injury or cerebral palsy. Positive effects of internet delivered therapies or video games were found from 33 reviews reducing headache, anxiety, pain and stress in both chronic and acute pain. One review found a small advantage for computerized cognitive training for executive function with the remaining 38 suggesting moderate effects to promote improvements in procedural learning. Reviews (n=55) focusing on treatment adherence found little effect over and above direct intervention with some support for use in serious mental health.

Conclusion: The reviews included in this systematised review highlight the potential of VR for use in rehabilitation across a number of contexts. Limitations to research methodologies within the reviews, differences in protocols and delivery modes and lack of standardization of outcomes preclude recommendations for practice. However the increase in studies across broad areas of clinical practice indicate exciting prospects for the use of VR technologies in rehabilitation.

***Keywords**: systematized review, rehabilitation, evidence* **Important note on Copyright:** The copyright agreement is appended at the end of this file. By submitting your paper to ICDVRAT you hereby agree to the Terms and Conditions of the Copyright Agreement.

1. INTRODUCTION

Motor and cognitive rehabilitation of disorders of brain development or acquired injury, disease or disability remains one of the great challenges to health professionals, particularly physical and occupational therapists, psychologists, and neuropsychologists. Furthermore pain, particularly low back pain, is a common but difficult to treat symptom leading to long-term sick leave and early retirement and as such, a high economic burden to societies (Ekman et al., 2005; Gaskin & Richard, 2012). Taken together there is an urgent need to identify solutions for increasing access to and effective implementation of rehabilitation therapies.

Over the past 20 years, there has been an increase in the use of technologies, particularly virtual reality (VR) technologies within rehabilitation practices. VR has been defined as "an artificial environment that is created with software and presented to the user in such a way that the user suspends belief and accepts it as a real environment"(https://whatis.techtarget.com/definition/virtual-reality).TheVR industry has developed exponentially, particularly in the gaming and entertainment arenas. Modes of access, applications (Apps) and use vary and may influence not only the extent to which an individual may feel engaged within the environment, but also impact on the extent to which particular technologies and environments may contribute any therapeutic benefit.

In rehabilitation settings, VR aims to improve motor or cognitive skills to support development and or reacquisition of functional skills. VR has been used in various ways in rehabilitation from training of movements of the upper or lower limbs, addressing problems in balance or posture, treating phantom and or chronic pain to games and environments to promote memory and visual spatial functions. The 'patient' populations who may receive VR training are diverse and include for example stroke patients, dementia, lower limb amputees, spinal cord injury and acquired brain injury as well as individuals cerebral palsy or people with lower back pain.

The form and contexts for VR vary in the extent to which the person is 'immersed' or 'suspended' in the environment. Projected images and desk top images differ in methods of 3-D imagery and extent to which peripheral vision supports the embeddedness within the environment, with head-mounted displays enabling more fully immersive experiences. VR may involve simulations in which the person has the impression of, for example, really flying a plane, or through the use of avatars which act in the environment or within 3-D video games. Extensions of VR technologies include augmented reality (AR) which blends real images or tangible (haptic) user devices in computer generated images and mixed reality (MR) aims for the merging of real and virtual worlds to create new environments. Furthermore, VR systems may be coupled with other technologies such as use of treadmills interlinked with VR environments or robotics to control more specific mobilisation of limbs for sensory-motor rehabilitation.

As an assistive technology, VR has been introduced for example as a training tool for wheelchair users to become accustomed to moving around in different environments using a head-mounted display (HMD) and assistive switch such as a joystick (Harrison et al., 2002). Wheelchair users can navigate a virtual world such as a simulated busy street or shopping centre to learn how to avoid obstacles and navigate inaccessible situations in a virtual setting before putting these into practice in the real world. The aim of this technology is to enable people with disabilities to lead an independent life wherever possible.

Use of commercial consoles and games that have undergone expert software development (e.g. gamification), are competitive with bespoke developed packages and acceptable in principle to young people with disabilities (Glegg et al., 2018); albeit their potential to impact on functional skills has undergone more limited examination. Further, commercial systems/games offer potential for therapy to be accessible and affordable, delivered within home or community environments, without the costs of bespoke systems or limits to the number of games developed for these systems (Deutsch et al., 2008: Reid and Campbell, 2006). However, accessibility to commercially produced systems either, physically to set up or manage the consoles (including the Nintendo Wii Balance board) or adjustments to visual-perceptual requirements or speed of the games may restrict use (Farr et al., 2019); thus limiting capacity of commercial products for therapeutic use.

Considering the breadth of VR developments, it is not hard to imagine the multiple different contexts that this emerging technology can be applied to, beyond the gaming and entertainment world, and in particular the multiple outcomes of VR used in therapeutic contexts. In view of the potential scope for applications of VR in rehabilitation, there is a need for a consistent language and framework to consider not only the mechanisms and processes of VR technologies within rehabilitation, but importantly defining the outcomes that might be facilitated. The International Classification of Functioning (WHO, 2001) is a useful construct that provides a common language to consider the characteristics of the individual, influences of environments and how these may interact on activity performance and participation. The ICF framework can thus contribute to the categorisation of outcomes to aide interpretation of the effects of various VR technologies and protocols used in rehabilitation practice.

Multiple studies are emerging which reflect the increased use of VR in rehabilitation, yet uptake has trailed behind opportunities made available by the exponential development of commercially available apps and VR technologies; which may or may not have potential for therapeutic benefit. This review aims to pull together reviews of VR to consider the evidence across contexts of rehabilitation practice. Corresponding to the themes of the VR4REHAB InteReg project the review focused on predominant challenges in rehabilitation: lower and upper limb function; pain; memory impairments and treatment adherence. Our research question thus considered: What evidence is there for benefits of Virtual Reality in Rehabilitation? And, specifically what outcomes are positively impacted across our five identified challenges?

2. METHOD

2.1 Study Design

In order to combine the strengths of a critical review with a comprehensive search process to provide an exhaustive search and best evidence synthesis mapped against the ICF (Grant & Booth, 2009).

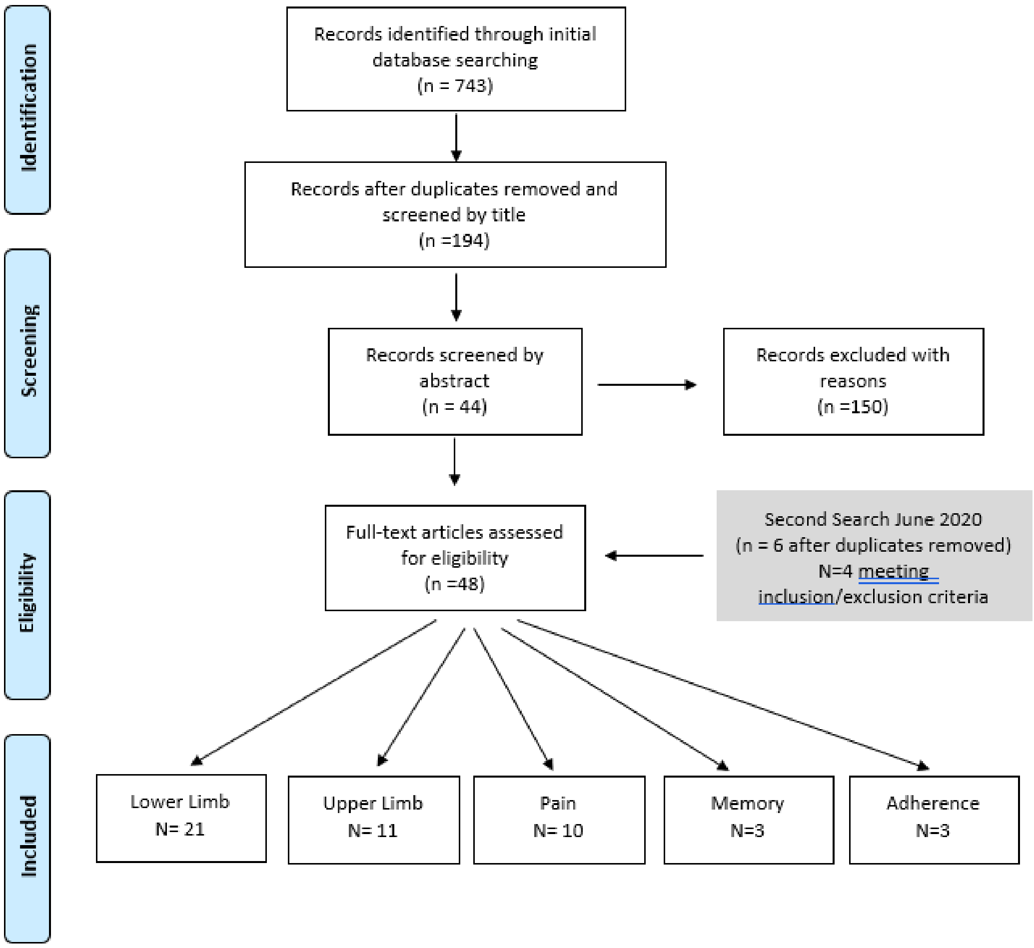
2.2 Search

Key search terms were agreed by consensus meeting of four authors (NL, DG, CM, DM) Boolean operators of AND or OR were used to include review articles with primary search terms of Virtual Reality (VR) or related synonyms (e.g. simulated 3D environment) with five searches across the different themes undertaken in each database 1) Lower limb and lower limb functions; 2) Upper limb and upper limb functions; 3) Pain (chronic pain or long term pain) 4) Memory and 5)Adherence. See Table 1 for details of search terms.

Table 1. PICO framework and Search Terms

	Problem	AND Intervention/Interest	Comparison	Outcome
All	(As per theme)	Virtual Reality OR Augmented Reality OR (Interact* AND Technology) OR Simulat* OR Immersi*	Rehab* OR Therap* OR Treatment OR Training OR Exercise	Outcome OR Effect* (no search terms)
Subtheme specification				
Lower Limb	(Move* AND Legs OR Lower Limb, lower extremit*) AND (Walk OR GAIT OR Posture OR Balance)			
Upper limb	(Move* OR Function* OR reach OR grasp OR holding OR bimanual) AND (Arm OR Hand OR Fingers OR Elbow OR shoulder)			
Pain	Chronic Pain OR Long Term Pain			
Memory	Memory OR Executive Function OR Impuls* OR Cognitive Flexibility OR Attention			
Adherence and Immersion	(Adherence OR Immersion OR Engage* OR Involv* OR Compliance OR Attend*)			

Comprehensive searches of electronic databases were initially conducted in MEDLINE (Ebsco) and the Cochrane Library between March and September 2019 retrieving full text articles in the English language. The search was repeated and expanded to include additional databases CINAHL (Ebsco), AMED (Ebsco), PsychINFO (ProQuest) and *IEEE Explore* on June 25 2020. The primary and secondary collection of literature and review of the articles was undertaken by the first author with two interns. The titles, abstracts or full texts of articles were screened for inclusion reflecting the following criteria: (1) systematic review as a research design; (2) involved intervention studies and 3) published in peer-reviewed journals. Manual search of reference list of articles selected for the full text review was conducted for any further articles that met the inclusion criteria. The second search was undertaken by the final author to identify any additional/recent articles meeting all inclusion and exclusion criteria. The Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA; (Moher et al., 2009) guidelines were followed for data extraction. Details of search, hits, exclusions are available on request and the search process is presented in figure 1.



From: Moher D, et al., The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement, PLOS Med 6(7): e1000097. Doi: 10.1271/journal.pmed100009

For more information, visit www.prisma-statement.org

Figure 1. PRISMA figure of Search Process

2.2 Selection of articles for narrative synthesis

A table was created summarizing the study type of each review, typology of population, age of participants, primary and secondary outcomes, measurement techniques and results of each article. Review articles were selected for consideration of treatment effects when the systematic review included empirical studies, with randomised controlled trials are well controlled cohort studies and effects on objective and or patient reported outcomes clearly reported. Articles were excluded when these were more narrative reviews (e.g. Chen et al., 2019 was excluded as these authors presented the merits and limitations of VR and other technologies for home based intervention rather than reported on effects of VR delivered at home).

2.3 Categorisation of Outcomes
In order to identify the effects of VR technologies within rehabilitation, outcomes of identified studies were coded using the ICF to better understand potential effects of VR in rehabilitation. The ICF was usedprovide a common language to communicate findings across the diverse inter-disciplinary groups involved in the development and implementation of VR technologies in rehabilitation. Outcomes identified in studies ranked as moderate to high quality were assigned codes according to the ICF domains of Body Structure and Function, Activities and Participation, and Environmental Factors. Coding criteria used previously were applied to ensure meaningful concepts were linked to the most precise ICF category in an objective manner (Cieza et al., 2016).

3. RESULTS

From a total of 743 hits after duplicates were removed and titles, abstracts screened and a further six papers identified, 201 full text articles were identified of which 48 met eligibility criteria for detailed narrative synthesis, two of which were IEEE conference proceedings. These are discussed across the five challenges of the VR4REHAB project: lower and upper limb function; pain; memory impairments; and, treatment adherence. See table 1 for distribution

Table 1. *Review distribution*

Challenge	*Hits (%)* N=743	*Full text Identified* N=202	*Narrative Comparison* N=48
Lower Limbs	92 (13)	21 (10)	21 (44)
Upper Limbs	273 (37)	53 (26)	11 (23)
Pain	64 (9)	33 (16)	10 (21)
Memory	112 (15)	40 (20)	3 (6)
Treatment Adherence	202 (27)	55 (27)	3 (6)

3.1 Evidence across VR rehabilitation challenges

3.1.1 Lower Limb Twenty one reviews were identified, one of which also reported on upper limb outcomes. Most reviews focused on stroke survivors (n=11(with others containing patients with multiple sclerosis (n=2), Parkinson's Disease (n=1), Cerebral Palsy (n=2), Traumatic Brain injury (n=1) Spinal Cord injury (n=1), Elderly n+10, mixed neurological disorders affecting balance and gait (n-1) and one involving health community dwelling adults (n-1). The summary from Cochrane reviews reflects insufficient good quality evidence to reach conclusions about the effect of virtual reality. Across other data bases, VR showed beneficial effect on gait and balance functions in elderly, MS patients, individuals with CP and patients with traumatic brain injury and stroke patients. Sitting and standing balance was seen to benefit Spinal Cord injuries although outcome measures were less reliable.

3.1.2 Upper Limb Eleven reviews were identified, again involving predominately stroke survivors (n=8), children with CP (n=2) and Spinal Cord Injury (n=1). Strong evidence is demonstrated for improvements in body function measures with less consistent evidence of transfer to activities of daily living across groups. Comparisons are confounded due to differing impacts on cognitive functioning, chronicity of stroke/age of children as well as mixed intensities and durations of therapy protocols and or combination with electromechanical and robot assisted arm training.

3.1.3 Pain

3.1.3 Pain Ten reviews addressed different aspects of pain. Four studies loosely used VR technologies via internet/video games or remote interventions when interventions explore more psychological therapies to address chronic pain in children (n=1) and adults (n=1), phantom limb pain (n=1) and pain and anxiety pre-post anaesthetic procedures in children (n=1), Positive effects of these approaches were evident for reducing headache, anxiety, pain and stress Mixed effects were seen from six studies that used VR particularly focussing on pain and fear, analgesic procedures, burn patients and for use as a distraction (n=3). The extent of immersion in interactive VR appeared to contribute to effects on pain.

3.1.4 Memory Three reviews focused on maintaining cognitive function in healthy (n=1), at risk of cognitive decline (n-1) and memory rehabilitation across a mix of memory impairments (n-1). One Cochrane review found a small advantage for computerised cognitive training for executive function with moderate effects on computerised cognitive training and VR cognitive training in long-term improvement of cognition or procedural learning in people with memory impairments.

3.1.5 Treatment Adherence Three reviews focussed on treatment adherence, reporting on compliance with intervention protocols in mental health (n-1), serious mental illness (n-1) and posttraumatic stress disorder (PTSD; n-1). The Cochrane Review concluded that VR had little effect regarding adherence/compliance in people with serious mental illness. While positive results were suggested for VR exposure therapy for PTSD, methodological issues reduced the quality of the evidence with particular problems in randomisation procedures, assessor blinding and methods for monitoring treatment adherence.

3.2 Impact on Outcomes mapped to ICF

Outcome measures and those which presented positive effect sizes were related to ICF domains of body function. See Table 2. The majority of these focused on body functions rather than activity performance or participation outcomes which may translate to daily life outside of clinical/experimental conditions.

Table 2. *Categorisation of outcomes by ICF domains*

Body Functions (b)
Mental functions (b1) **Specific mental functions (b140-b189):** **Higher-level cognitive functions (b164)** Cognitive flexibility (b1643) **Psychomotor functions (b147)** Psychomotor control (b1480) Quality of psychomotor functions (gait) (b1481) **Emotional functions (b152)** Emotional functions, other specified (b1528)
Sensory Functions (b2) **Vestibular function of balance (b235)** Sensory functions of the inner ear related to determining the balance of the body (b2351) **Note Sensation of falling not recorded. B2402** **Sensitivity to a noxious stimulus (Pain)(b2703)**
Functions of the cardiovascular system (b410-b429) **Additional functions and sensations of the cardiovascular and respiratory systems (b450-b469)** Exercise tolerance functions (b455) (fitness see d570) Fatiguability (b4552)
Muscle Power functions
Power of muscles of one (b7301)
Movement Functions (b7)
Power of muscles of one limb (b730) **Muscle functions (b750)** **Control Gait pattern functions (d770)** **Muscle Power functions (b730)** **Control of voluntary movements (b760)**

Coordination of voluntary movements (b7602) **Involuntary Movement functions (b765)** Tremor (b7651) **Muscle functions not specific (b789)** Range of movement	
Activity and Participation (d)	**Environmental Factors (e)**
Mobility (d450–d460 Walking and moving) **Changing basic body position (d410-d429)** Changing body position from sitting, standing to moving around.	**Attitudes (e4)** Not covered
Carrying, moving and handling objects (d430-d449)	
General tasks and demands (d210-d299) Handling stress and other psychological demands (d240)	**Services, systems and policies (e5)** Not covered
Looking after oneself (fitness) (b570)	
Community, social and civic life (d9)	**Services, systems and policies for the production of consumer goods (e510)** Not covered **General social support services, systems and policies (e575)** Not covered
Recreation and leisure (d920)	

4. CONCLUSION

This systemised search and reviewed identified a number of systematic reviews across different domains of rehabilitation practice. While no specific recommendations can be made in view of the breadth of practice, the multiple combinations and variety of methods of VR (ranging from bespoke platforms to use of commercial products and video games) the potential for positive effects of VR technologies in rehabilitation have been demonstrated.

Outcomes reflecting significant effect sizes were predominately represented by measures of body functions with few looking at the translation to activity performance and participation. The mapping of VR research outcomes to ICF classifications helps to bridge research to daily contexts. However, it is not clear whether this represents the relative ease of which it is possible to measure body function outcomes such as stride length or reach or grasp strength as opposed to walking around a supermarket and reaching for and obtaining items to put in a shopping trolley. More research is needed to consider the translation of experimental studies to daily life.

Importantly, detailed reporting on study protocols is recommended, particularly with respect to dose and intensity as well as mechanisms of access with future reviews contrasting more precisely different mechanisms of VR and treatment dosage. Additionally, concerns were evident across some of the studies in which methodological limitations compromised interpretation of findings, particularly with respect to: a) Recruitment methods and populations were poorly described, b) blinding and use of more objective measures of outcomes and c) Intervention location and environment and frequency of contact with a specialist or therapist are clearly detailed. There is a need to bridge the results of rigorous quantitative techniques used in clinical and experimental trials to demonstrate viable and meaningful outcomes for the individuals and their families to promote adoption of successful interventions into practice.

Considering the theoretical potential of VR to modulate health status, relatively few potential outcomes across activity performance and participation were addressed in the studies. It is an imperative for future research into the potential benefits of VR in rehabilitation, that meaningful patient/client perspectives are considered as primary outcomes. This information is vital in order to support translation of experimental trials to clinical practice.

Acknowledgements: Thanks go to our two interns for undertaking the initial searches and collating of information.

REFERENCES

Chen, Y., Abel, K.T., Janecek, J.T., Chen, Y., Zheng, K., & Cramer, S. C. (2019). Home-based technologies for stroke rehabilitation: a systematic review. *International journal of medical informatics*, *123*, 11-22.

Cieza A, Bickenbach J, Prodinger B, Fayed N. Refinements of the ICF Linking Rules to strengthen their potential for establishing comparability of health information. Disability and Rehabilitation. 2016:1-10.Ekman, M., Johnell, O., & Lidgren, L. (2005). The economic cost of low back pain in Sweden in 2001. *Acta orthopaedica*, *76*(2), 275-284.

Davies, K.S. (2011) Formulating the evidence based practice question: a review of the frameworks. Evid Based *Libr Inf Pract,* ;6:75-80.

Deutsch, J. E., Borbely, M., Filler, J., Huhn, K., & Guarrera-Bowlby, P. (2008). Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. *Physical therapy*, *88*(10), 1196-1207.

Farr, W. J., Green, D., Bremner, S., Male, I., Gage, H., Bailey, S., Speller, S., Colville, V., Jackson, M., Memon, A., & Morris, C. (2019). Feasibility of a randomised controlled trial to evaluate home-based virtual reality therapy in children with cerebral palsy. *Disability and Rehabilitation*, 1–13. https://doi.org/10.1080/09638288.2019.1618400

Gaskin, D. J., & Richard, P. (2012). The economic costs of pain in the United States. *The Journal of Pain*, *13*(8), 715-724.

Glegg, Stephanie Miranda Nadine, & Levac, D. E. (2018). Barriers, Facilitators and Interventions to Support Virtual Reality Implementation in Rehabilitation: A Scoping Review. *PM&R*, *10*(11), 1237-1251.e1. https://doi.org/10.1016/j.pmrj.2018.07.004

Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Info Libr J.* 2009;26(2):91-108.

Harrison, A., Derwent, G., Enticknap, A., Rose, F. D., & Attree, E. A. (2002). The role of virtual reality technology in the assessment and training of inexperienced powered wheelchair users. *Disability rehabilitation*, *24*(11-12), 599-606.

Reid, D., & Campbell, K. (2006). Randomized Trial. *Therapeutic Recreation Journal*, *40*(4), 255-68.

World Health Organization (2001) *International classification of functioning, disability and health: ICF*. Geneva: World Health Organization.

Evaluation of a virtual reality tandem-bike exergame for rehabilitation

Emil Rosenlund Høeg[1], Jon Ram Bruun-Pedersen[1], Shannon Cheary[3], Lars Koreska Andersen[1], Razvan Paisa[1], Stefania Serafin[1], Belinda Lange[2]

[1]Department of Architecture, Design and Media Technology, Aalborg University,
A.C. Meyers Vænge 15, Copenhagen S, DENMARK

[2]College of Nursing and Health Science, Flinders University,
Sturt Rd, Bedford Park 5042, South Australia, AUSTRALIA

[3]Division of Rehabilitation, Aged Care and Palliative Care, Flinders Medical Centre,
Flinders Drive, Bedford Park 5042, South Australia, AUSTRALIA

[1]*{erh,jpe,lka,rpa,sts}@create.aau.dk*, [2]*belinda.lange@flinders.edu.au*, [3]*shannon.cheary@sa.gov.au*

ABSTRACT

Virtual Reality (VR) technology is constantly tested and implemented in various different rehabilitation programs. For older adult patients social VR-experiences may reduce the risk of loneliness, but there may be potential negative consequences of using competitive rather than collaborative game designs. We conducted a mixed methods user study to gather feedback on a collaborative VR tandem bike scenario. All participants indicated that they found the social aspect enjoyable, and that it was easier to complete the task with others. Future studies should explore location and appearance of the virtual co-actors, as well as implement additional collaborative tasks.

1. INTRODUCTION

With a growing global geriatric population there is a high demand for new and innovative rehabilitation equipment and devices. However, according to previous research, health-related outcomes are frequently determined by human behavior rather than the number of technical breakthroughs (Schroeder, 2007). Therefore, it is equally vital to explore different user preferences in vastly heterogeneous populations than it is to simply expand on the technical innovations that constitute methods of delivering the therapy. Virtual reality (VR)-based rehabilitation is a growing field, and more interventions are being implemented in clinical settings e.g. to increase adherence by placing the patient in novel, interesting and enjoyable virtual environments (Keshner et al, 2019). Stationary bicycles are commonly used as a versatile and safe rehabilitation and exercise technology, that has largely remained unaltered. However, many previous studies have attempted to augment repetitive cycling through various game-inspired mechanics (Gallagher, 2016; Høeg, 2021). Rehabilitation can be a socially isolating and lonely experience for some patients (Bernhardt, 2004), and social consequences may arise when using a technology that encapsulates its users within a highly subjective experience. While some studies have incorporated social aspects into rehabilitation interventions to increase motivation (Marker and Staiano, 2015; Goršič, 2019; Pereira, 2021), the majority have relied on competitiveness rather than collaborative concepts. Competitiveness in games can lead to feelings of stress and aggressive behavior. For older adults, who engage in activities where defeating another player is endogenous, a failure to succeed may undermine intrinsic motivation and potentially be detrimental to their enjoyment, well-being and adherence. The limited evidence for collaborative game principles and potential negative consequences of competitiveness, supports further research into the effects of collaboration and social presence in VR-based rehabilitation.

2. METHODS

This project presents a mixed methods usability study to gather user feedback on a collaborative VR scenario that encourages co-located players to work together by completing a biking-based scenic ride on a tandem bike in VR. Current or discharged clients in an outpatient setting were invited to participate with a co-player (friend, family or an unfamiliar person). All participants (n=11, 64% males, 60±11 years) experienced the VR activity on an exercise bike with a partner. Side effects (Simulator Sickness Questionnaire – SSQ), system usability (System Usability Scale – SUS), motivation (Intrinsic Motivation Inventory - IMI), embodiment (Virtual Embodiment Questionnaire) and inter-player interaction (Interpersonal Interaction Questionnaire) was measured and participants provided additional feedback in a post-test semi-structured interview.

3. RESULTS

Results of the study indicate potential and feasibility for the collaborative social biking application with an excellent SUS score (85±5) and high intrinsic motivation in all categories: Enjoyment (6.5±0.7), effort/importance (6.1±0.7) and relatedness (6.4±0.6). Participants biked on average 10.6 (±2.6) minutes with a mean speed of 14.6 kmph (±5.3). Side effects (SSQ) were only a minimal acceptable increase (mean change score) in nausea (16.5±13.6), oculomotor (5.5±11.3), disorientation (6.3±9.6) and total scores (8.5±8).

4. DISCUSSION AND CONCLUSION

All participants expressed that they found the social aspect enjoyable, and felt that it was easier to complete the task when collaborating with a biking buddy. Moreover, they generally lost track of exercise duration. Real world interaction between co-players varied in quantity but was mostly positive. The sense of co-presence was limited by physical constrains and poor (avatar) representation. Most participants said they would use the program again, but future studies should explore how to improve the location and appearance of the co-actors, as well as implement additional collaborative tasks.

5. REFERENCES

Bernhardt, J., Dewey, H., Thrift, A., & Donnan, G., (2004), Inactive and alone: physical activity within the first 14 days of acute stroke unit care, *Stroke*, **35**, 4, pp. 1005-1009.

Gallagher, R., Damodaran, H., Werner, W. G., Powell, W., & Deutsch, J. E., (2016), Auditory and visual cueing modulate cycling speed of older adults and persons with Parkinson's disease in a Virtual Cycling (V-Cycle) system, *Journal of NeuroEngineering and Rehabilitation*, **13**,1, pp. 1-11.

Goršič, M., Cikajlo, I., Javh, M., Goljar, N., & Novak, D., (2019), Pilot Long-term Evaluation of Competitive and Cooperative Exercise Games in Inpatient Stroke Rehabilitation, *IEEE 16th International Conference on Rehabilitation Robotics (ICORR)*, pp. 648-653). IEEE.

Høeg, E. R., Bruun-Pedersen, J. R., & Serafin, S., (2021), Virtual Reality-Based High-Intensity Interval Training For Pulmonary Rehabilitation: A Feasibility and Acceptability Study, *IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pp. 242-249

Keshner, E. A., Weiss, P. T., Geifman, D., & Raban, D., (2019), Tracking the evolution of virtual reality applications to rehabilitation as a field of study, *Journal of NeuroEngineering and Rehabilitation*, **16**, 1, pp. 1-15.

Marker, A. M., & Staiano, A. E., (2015), Better together: outcomes of cooperation versus competition in social exergaming. *Games for health journal*, **4**, 1, pp. 25-30.

Pereira, F., i Badia, S. B., Jorge, C., & Cameirão, M. S., (2021), The use of game modes to promote engagement and social involvement in multi-user serious games: a within-person randomized trial with stroke survivors. *Journal of NeuroEngineering and Rehabilitation*, **18**, 1, pp. 1-15.

Przybylski, A. K., Deci, E. L., Rigby, C. S., & Ryan, R. M., (2014), Competence-impeding electronic games and players' aggressive feelings, thoughts, and behaviors, *Journal of personality and social psychology*, **106**, 3, pp. 441-457.

Schroeder, S. A., (2007), We can do better—improving the health of the American people, *New England Journal of Medicine*, **357**, 12, pp. 1221-1228.

Augmented Reality and Real-Time Feedback for Physical Therapy

L. Lancere[1], I. Kugaudo[2]

[1] Socio-technical Systems Engineering Institute, Vidzeme University of Applied Sciences,
Terbatas street 10, Valmiera, LATVIA

[2] Fanout, ltd., Riga, LATVIA

[1]*linda.lancere@va.lv*

[1]*www.va.lv*

ABSTRACT

This paper describes a novel physical therapy solution that consists of integrated wearables, augmented reality, and a software platform. Targeted activation of deep core muscles and breathing training are prescribed in general physical therapy as well as in low back pain rehabilitation. The concept is to provide real-time feedback from wearable devices – surface electromyography sensors and respiratory inductance plethysmography belt - to optimize the engagement of the deep core muscles during exercise by means of Hololens 2 and Biosignalplux devices. The requirements, architecture, design considerations, as well as system evaluation (System Usability Score), are described in the paper.

1. INTRODUCTION

The most recent global estimates show that one in four (27.5%) adults do not meet the recommendations for aerobic exercise. Physical inactivity has high incidence in; low back pain 80% of population, 6% of deaths globally, 22% of heart disease, 12% diabetes and hypertension (Bull et al., 2020).

There is a variety of technological solutions developed for rehabilitation purposes, including motion capture (Su, Yeh, et al., 2015), video feedback (Don et al., 2019), virtual reality (Alazba et al., 2018). Recently VR has shown efficacy on treatment for low back pain treatment and maintaining higher physical activity level in general (Stamm et al., 2020)(Tack, 2019) (Trujillo et al., 2020)(Mbada et al., 2019).

There are several downsides for both VR and AR applications. The existing augmented reality (AR) solutions are focused on stroke rehabilitation for upper limbs (Hondori et al., 2013), as a tool for distraction during painful procedures (Griffin et al., 2020) and posture correction (Williams et al., 2019). The VR applications are focused mainly on cognitive behavioural therapy, activity level in general, these applications are limited in a 3D space depth and the capturing area. Kinect and motion capture systems have the dimensional limitations, movements can be compensated with different muscle group which can't be identified using these systems. Due to physiological and cognitive disturbances because of the aging process, the elderly population is in a higher risk group for motion sickness and psychological overwhelming in the immersive virtual reality environment.(Sagnier et al., 2021)(K.-Y. Kang, 2015)(Stamm et al., 2020). Therefore, in order to provide patient-specific and objective information from the target muscles groups, as well as to decrease possibility of motion sickness, an alternative solution is proposed.

2. METHODS

2.1. Physical therapy approach

The ARehab system is intended for deep muscle activation using visual feedback. The target user is a person in an age group of 16+, applied with the help of a physical therapist. It is beneficial to a healthy user; as well as to those with low back pain, sedentary, amputee or other individuals in a need for strengthening deep core muscles and improving their quality of movement. The only limitations of the method relate to technical causes – associated to the placement of sensors, signal quality (body constitution) and user's ability to follow audio/visual feedback.

Targeted activation of deep core muscles and pursed lip breathing training are prescribed in general physical therapy as well as in low back pain rehabilitation and prevention programs.(Chang et al., 2015) Deep core muscles

as part of lumbopelvic-hip complex (LPHC) play a crucial role in efficient movement control (Granacher et al., 2013). Due to the complexity of the deep muscle identification and lack of direct feedback in the traditional approaches, the proposed solution involves surface electromyography (sEMG) sensors. Feedback from sEMG sensors has been proven to increase the motivation, motor and self-control re-training efficiency. (Neblett, 2016). For the proposed solution sEMG sensors are placed on the deep core muscles (multifidus and transversus abdominis), accordingly the exercise program is focused on the mentioned muscle activation increase and control.
Equipment. The offered novel system (ARehab) setup consists of sEMG and respiration sensors and Hololens 2 head mounted display (HMD) (figure 1). The respiratory inductance plethysmography (RIP) belt (Løberg et al., 2018) is placed between the 10th rib and umbilicus. The sEMG sensors are placed on Transversus Abdominis and Multifidus bilaterally according to SENIAM guidelines (http://www.seniam.org/) - 1 cm medial to the anterior superior iliac spine for Transversus Abdominis muscle and at the level of L5 spinous process (i.e., about 2 - 3 cm from the midline) for the Multifidus muscle. Range ±1.5mV, bandwidth 25-500Hz.
Exercises. The exercise program consists of two exercises to begin in default: pursed lip breathing and Transversus Abdominis activation training. These two are followed by exercises targeted to the deep trunk muscle activation – Bent Leg Raise, Back Bridge, Side Plank, Chair Lean with Resistance Band. The choice of exercises is based on the previously performed study using visual feedback (Lancere & Wilken, 2020). A video demonstration of the exercise and countdown are demonstrated in the Hololens 2 headset before and during each exercise.
Calibration: The user is asked to perform maximal inhale with abdomen and abdominal muscle strength test by Kendall to establish the maximal values of the specific user. These values are used to determine maximal thresholds for the visual feedback.
Visual feedback. The visual feedback depends on the data from the respiration and muscle activity sensors in real-time while performing exercises. Depending on the exercise step, the data from either RIP belt or sEMG sensor specific channel alters the diameter of the green circle (figure 1). The circle diameter increases if the numeric values increase meaning abdominal expansion or increase in the muscle electric activity.
How to perform the sequence: After the two calibration steps, the user performs the sequence of exercises. Video instruction of the entire exercise is provided before each of exercises. The user is instructed to fill the circle both when inhaling and when contracting the deep muscles. When the user is ready to start the exercise, he/she gives verbal command “start!” which is then followed by a visual and audial countdown during the inhalation or movement. The sequence can be changed or paused by the Physical Therapist in the control panel.

2.2. System Setup

The high-level system consists of four main blocks - input/sensors, server, the Web Browser Client, the Hololens Client. Development programming languages used are Java, JavaScript and C# in Unity engine. All exercises are splitted into steps. *1. Input/sensors.* The Plux sensor broadcasts a live data stream over Bluetooth to the Bitalino OpenSignals application, then further to a chosen port over Transmission Control Protocol (TCP).
2. The ARehab server is a standalone Java application driven by the open-source Spring Framework. The server consists of multiple data transmission layers. Layer 1 establishes TCP connection to OpenSignals, sends commands, and receives a raw data stream. Layer 2 applies filters for the raw data. Layer 3 transforms the accumulated data according to the current workout step. Layer 4 accepts incoming TCP connections and broadcasts the effort data. Layer 5 broadcasts the data over the Web sockets, so the web browser client can show execution flow and allow an operator to manipulate it. Layer 6 sends the data to the Logstash storage. *3. The web browser* client is implemented as a JavaScript application packed as a part of the server. It connects to the server web socket layer and allows manipulating the steps in real-time. *4. Hololens client* is implemented it as a standalone Unity application. The application loads the workout data from the server before the workout start. The client receives the data broadcast during the workout process. The Unity client draws the real-time charts, playbacks media files. Workout configuration meta-language is used to describe the patient workout steps. All the steps are loaded to the workout. When the workout starts the Unity client requests the server for the step sequence and receives the sorted list with all required fields. Then, in real-time the server notifies Unity the specific step number and patient effort magnitude, so the Hololens can show an appropriate media file or the visual feedback. ARehab server uses the dynamic data buffering strategy for the broadcast, so that if Unity can’t read the stream as fast as server sends it, the server reduces the frequency to gain the perfect pixel-in-pixel results.

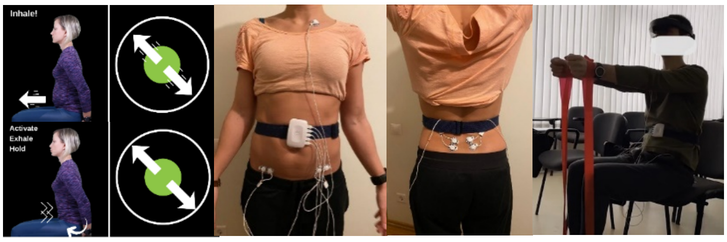


Figure 1. *Visual feedback related to respiration and muscle activity real-time and sensor placement.*

The system allows adding several new input and output devices both to obtain the information from the user (sensors) and to provide visual/auditory feedback (HMDs) based on the sensor data in real-time during exercising. The operator can change the exercise setup remotely thus significantly increasing PT's capacity and optimising the rehabilitation time since the program is individualized according to patient specific data.

3. STUDY SETTING

The evaluation process was performed during one session which consisted of 3 parts: introduction of the technology and the process, performing the exercises and filling the questionnaires. The evaluation procedure was confirmed by Latvian Physical Therapy Association ethics committee. The setup was tested by fourteen physical therapists from private clinics and from hospital rehabilitation departments.

First, the Physical Therapists filled questionnaires on their professional experience and most common patient diagnosis. After a brief explanation of the procedure, therapists performed the exercise sequence in the HMD to fully evaluate the process that their patient would need to undergo. Physical Therapists were asked to perform the tests trying to follow only the information they see and hear in the Augmented Reality without any outside help. Then the specialists filled the System Usability Scale (SUS) and subjective satisfaction questionnaire. SUS is a reliable and valid measure of perceived usability. To obtain more detailed understanding about respondents' opinions and different aspects of such a complex system, focus group approach was used. Specialists were asked about their opinion on augmented reality headset applicability, necessity to use wearables, visual feedback in their practice, user experience. The data was logged and tracked using a participant code and time date code (alphanumeric subject ID and/or YYYYMMDD_TTTT). The data was analysed based on SUS methodology.(Brooke, 1996)

It must be noted that the testing was performed in an early protype stage to be able to perform alterations according to the potential target user's feedback according to their real-life requirements.

4. RESULTS AND CONCLUSIONS

The average age of Physical Therapists was 30y (23; 56) with working experience 7 years (1; 33). The most common treated medical conditions on every day basis were stated Spinal complications (hernia etc.) 71%, Low Back Pain 76%, Neurological conditions 48%, Elderly and Sportsmen 47%, Obesity 46%, after Orthopaedic surgeries 37%, Cognitive Impairment 35%, Cardiovascular conditions 33%, Pulmonary conditions 30%.

The SUS percentile rank was 66 which is below the average. When analysing the answers, it was noticed that there is a significant amount answers graded as "neutral". The result is influenced by the comparingly small testing population, and the work needs to be expanded.

Previous use of technologies: Only one of the respondents had had previous experience with virtual technologies or wearables and during discussions respondents confirmed they would need some time to adjust for the new experience. It was indicated that the adapting time greatly depends on the previous experience with technologies and the user's cognitive state. *Focus group discussion/visual feedback:* When asked outside from the SUS questionnaire, 82% of the testers confirmed that they would use visual feedback in their practice periodically, or on everyday basis. 21% said the visual information was hard to process.

Motivation, self-awareness and time: Only one of the respondents disagreed that the offered solution would save the Physical Therapist's time. 80% agreed that the offered application would increase the patient's motivation, 50% thought the patient's self-awareness would increase. The introduction time for the user varied from 5-20minutes during the first session to several sessions. 64% confirmed that the rehabilitation program would be more patient cantered using the proposed system.

UX/UI: 80% confirmed that the instructions aligned with the actions demonstrated in the AR, and there were no situations when one should try to remember what needs to be done next, it was clear how to use the system from the technical point of view. 50% of respondents said they felt comfortable, and they would use the headset for their patients. 14% were afraid the headset would fall during the activities.

Majority of the respondents indicated that there are parameters that require individualization, for example, the speed of the audial and visual feedback, the time between instructions. It is important to note that specialists confirmed that the proposed system would be applicable to patients with wide range of medical conditions.

The main conclusions are that there is a high interest and necessity for a complex real-time visual feedback providing systems and we have received a confirmation that the proposed system are highly suitable for rehabilitation applications. Meanwhile, it is clear the user experience, adjustability of the system and the previous experience with technologies play a crucial role in practical applications and is a challenge in the clinical setup.

Acknowledgements: Funding in frames of The State Education Development Agency and European Structural funds "Post-doctoral Research Aid" project no. 1.1.1.2/VIAA/2/18/357, Vidzeme University of Applied Sciences, Tērbatas str.10, LV-4201, Latvia. “Design Research for User-friendly Guidance of Complex Whole-body Rehabilitation for Lower Extremity Amputees by Means of Extended Reality and Advanced Wearables Data Processing”.

5. REFERENCES

Alazba, A., Al-Khalifa, H., & AlSobayel, H. (2018). RabbitRun: An Immersive Virtual Reality Game for Promoting Physical Activities Among People with Low Back Pain. *Technologies*, *7*(1), 2. https://doi.org/10.3390/technologies7010002

Brooke, J. (1996). SUS: A “Quick and Dirty” Usability Scale. In *Usability Evaluation In Industry* (pp. 1–6).

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*(24), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Chang, W.-D., Lin, H.-Y., & Lai, P.-T. (2015). Core strength training for patients with chronic low back pain. *Journal of Physical Therapy Science*, *27*(3), 619–622. https://doi.org/10.1589/jpts.27.619

Don, S., Venema, M., De Kooning, M., van Buchem, B., Nijs, J., & Voogt, L. (2019). Does Sensorimotor Incongruence Trigger Pain and Sensory Disturbances in People With Chronic Low Back Pain? A Randomized Cross-Over Experiment. *Journal of Pain*, *20*(3), 315–324. https://doi.org/10.1016/j.jpain.2018.09.011

Granacher, U., Gollhofer, A., Hortobágyi, T., Kressig, R. W., & Muehlbauer, T. (2013). The importance of trunk muscle strength for balance, functional performance, and fall prevention in seniors: A systematic review. *Sports Medicine*, *43*(7), 627–641. https://doi.org/10.1007/s40279-013-0041-1

Griffin, A., Wilson, L., Feinstein, A. B., Bortz, A., Heirich, M. S., Gilkerson, R., … Simons, L. E. (2020). Virtual reality in pain rehabilitation for youth with chronic pain: Pilot feasibility study. *JMIR Rehabilitation and Assistive Technologies*, *7*(2). https://doi.org/10.2196/22620

Hondori, H. M., Khademi, M., Dodakian, L., Cramer, S. C., & Lopes, C. V. (2013). A spatial augmented reality rehab system for post-stroke hand rehabilitation. *Studies in Health Technology and Informatics*, *184*(February), 279–285. https://doi.org/10.3233/978-1-61499-209-7-279

Kang, K.-Y. (2015). Effects of core muscle stability training on the weight distribution and stability of the elderly. *J.Phys.Ther.Sci.*, *27*(10), 3163–3165.

Lancere, L., & Wilken, J. (2020). Use of Real-Time Visual Feedback To Facilitate Core Muscle Activation In Individuals With Low Back Pain. *Archives of Physical Medicine and Rehabilitation*, *101*(12), e153–e154. https://doi.org/10.1016/j.apmr.2020.10.086

Løberg, F., Goebel, V., & Plagemann, T. (2018). Quantifying the signal quality of low-cost respiratory effort sensors for sleep apnea monitoring. *HealthMedia 2018 - Proceedings of the 3rd International Workshop on Multimedia for Personal Health and Health Care, Co-Located with MM 2018*, 3–11. https://doi.org/10.1145/3264996.3264998

Mbada, C. E., Makinde, M. O., Odole, A. C., Dada, O. O., Ayanniyi, O., Salami, A. J., & Gambo, I. P. (2019). Comparative effects of clinic- And virtual reality-based McKenzie extension therapy in chronic non-specific low-back pain. *Human Movement*, *20*(3), 66–79. https://doi.org/10.5114/hm.2019.83998

Neblett, R. (2016). Surface Electromyographic (SEMG) Biofeedback for Chronic Low Back Pain. *Healthcare*, *4*(2), 27. https://doi.org/10.3390/healthcare4020027

Sagnier, C., Loup-escande, E., Lourdeaux, D., Sagnier, C., Loup-escande, E., Lourdeaux, D., … User, G. V. (2021). User Acceptance of Virtual Reality : An Extended Technology Acceptance Model To cite this version : HAL Id : hal-02446117.

Stamm, O., Dahms, R., & Müller-Werdan, U. (2020). Virtual Reality in Pain Therapy: A Requirements Analysis for Older Adults with Chronic Back Pain. *Journal of NeuroEngineering and Rehabilitation*, *17*(129), 1–12. https://doi.org/10.21203/rs.3.rs-24221/v1

Su, W. C., Yeh, S. C., Lee, S. H., & Huang, H. C. (2015). A virtual reality lower-back pain rehabilitation approach: System design and user acceptance analysis. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *9177*(July), 374–382. https://doi.org/10.1007/978-3-319-20684-4_37

Tack, C. (2019). Disability and Rehabilitation : Assistive Technology Virtual reality and chronic low back pain. *Disability and Rehabilitation: Assistive Technology*, *0*(0), 1–9. https://doi.org/10.1080/17483107.2019.1688399

Trujillo, M. S., Alvarez, A. F., Nguyen, L., & Petros, J. (2020). Embodiment in virtual reality for the treatment of chronic low back pain: A case series. *Journal of Pain Research*, *13*, 3131–3137. https://doi.org/10.2147/JPR.S275312

Williams, R. M., Alikhademi, K., Drobina, E., Gilbert, J. E., & Sutor, T. (2019). Augmented Reality for Rehabilitative Therapy: Patient experiences and Practitioner perspectives. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 748–752. https://doi.org/10.1177/1071181319631140

Promoting physical activity using pervasive social games: case studies with elderly people in Brazil and Japan

L H O Santos[1,2,a], K Okamoto[1,2], S S Funghetto[3], A S Cavalli[4], R Otsuki[1], S Hiragi[1,2], G Yamamoto[2], O Sugiyama[5], C D Castanho[6], T Aoyama[5], T Kuroda[1,2]

[1]Graduate School of Informatics, Kyoto University,
Yoshidahonmachi, Sakyo Ward, Kyoto, JAPAN

[2]Div. of Medical IT and Administration Planning, Kyoto University Hospital,
54 Shogoin Kawaracho, Sakyo Ward, Kyoto, JAPAN

[3]Ceilândia Faculty, University of Brasília,
Campus Universitário, Centro Metropolitano, Brasília, BRAZIL

[4]Department of Sports, Federal University of Pelotas,
R. Gomes Carneiro, 1 - Centro, Pelotas, BRAZIL

[5]Graduate School of Medicine, Kyoto University,
Yoshida-Konoe-cho, Sakyo-ku, Kyoto, JAPAN

[6]Computer Science Department, University of Brasília,
Campus Universitário Darcy Ribeiro, Brasília, BRAZIL

[a]*lhsantos@kuhp.kyoto-u.ac.jp*

ABSTRACT

Pervasive games, due to their adaptive nature and casual gameplay, can be especially suitable to promote positive behavior and help elderly people. In this paper, we describe and compare two studies, in Brazil and Japan, in which we evaluated the effect of introducing social interaction as a design element of pervasive game targeting elderly players on their levels of physical activity.

1. INTRODUCTION

Protecting the health and promoting the quality of life of elderly people become increasingly challenging goals for society, as the proportion of senior citizens increases worldwide. In this context, promoting physical activity and preventing social isolation are especially relevant interventions that positively affect the quality of life of the elderly (Hagan, Manktelow, Taylor, & Mallett, 2014; Vagetti et al., 2014).

Interventions to promote physical activity have been object of study for many years now (Hallal et al., 2012; Romeo et al., 2019) and many studies have also explored strategies to prevent social isolation (Kay, Daykin, Lane, Meads, & Studies, 2018), with varied levels of success. In recent years, games, due to their potential of creating fun experiences and engaging users, have become object of great interest both commercially and in academia as a way to create positive behavior change and connect people. In particular, the emerging genre of pervasive games can be very effective for those purposes.

A pervasive game is an electronic game that blends elements from the real world into the world of the game (Montola, 2005), the most remarkable example being the extremely popular Pokémon GO (Niantic, 2016). Any element from the real world can be potentially used in the game, including the player’s location, aspects of their local environment, physical objects, social relations, and others. Because pervasive games are adaptive, integrating different aspects of player’s life, they focus on casual gameplay which allows people of diverse backgrounds and levels of experience to play together and interact through the game (Guo, Trætte, Wang, & Zhu, 2010; Marquet, Alberico, Adlakha, & Hipp, 2017).

Pervasive games can be especially suitable for elderly players, who usually prefer casual gaming experiences (Cota, Ishitani, & Vieira, 2015) and tend to have more flexible and dynamic lifestyles. Whether senior players are motivated by external factors, such as isolation or boredom, or by internal factors, such as inherent interest in games or on the theme of specific games (De Schutter & Malliet, 2014), they can still potentially find appeal in pervasive games, since the, due to their approach, these games allow different levels of engagement and different styles of playing.

Previous works have investigated the motivations of elderly people to play games (Carvalho & Ishitani, 2012; De Schutter, 2011; McLaughlin, Gandy, Allaire, & Whitlock, 2012) and many different games and gamified applications have been developed specifically to promote physical activity among senior players (Bleakley et al., 2015; Larsen, Schou, Lund, & Langberg, 2013) or to prevent social isolation and loneliness (Hagan et al., 2014), however, little focus was given on the effect of specific design elements of pervasive games on older adults.

In this paper we describe and compare the findings of two studies, one in Brazil and one in Japan, in which we evaluated the effect of introducing one design element – social interactions – in a pervasive game targeting elderly players. Due to its relevance to the quality of life of elderly people, we chose the promotion of physical activity as our target goal, while the social elements in the game also focus on prevention of loneliness and social isolation.

The remaining of this paper is organized as follows. In Section 2, we describe the methodology and experimental settings used in the studies. Section 3 presents a summary of relevant results and statistical analysis of the data. Section 4 discusses the findings and their repercussions. Finally, in Section 5, we conclude with our final remarks and possible future works.

2. METHODS

We developed a pervasive mobile game, called *Shinpo* in Japan (L. H. Santos, Okamoto, Hiragi, et al., 2019) and *Trilhas* in Brazil (L. H. Santos, Okamoto, Funghetto, et al., 2019). The same basic game was adapted to each culture, and a variation of it was created introducing social interaction elements. After that, a single single-blind quasi-experimental study was conducted in each country comparing two groups – with social interaction, and without social interaction. The next sections describe the game and the experimental settings.

2.1 Game

In our game, players must collect virtual cards (Figure 1) by visiting real locations within their city that are publicly accessible. Each card features an animal and a color, which indicates its level. There are four levels, and the goal of the game is to collect the card of highest level for all animals.

Figure 1. *Examples of cards from Shinpo and Trilhas.*

In the main screen of the game (Figure 2, a), players can see a map showing their current location and nearby hotspots. Hotspots were defined using Google Maps information about public places of interest, such as religious temples, supermarkets, government offices, etc. After visualizing nearby hotspots, players must physically walk towards them, and then “check in” to register a visit. If the game is open and the player’s speed exceeds a certain threshold, the game warns the player to not walk while looking at the smartphone.

A player receives a random Level 1 card for every unique hotspot they visit within a day, or for every 1000 steps they walk. The step count was measured using a background service that operated whenever the smartphone was turned on. This software used Google Android’s Sensor API, which is the same as the Google Fit, an application previously shown to have accuracy equivalent to or better than that of wearable devices (Case, Burwick, Volpp, & Patel, 2015). At any moment, players can trade 5 cards of the same animal and level for 1 card of the next level and same animal (Figure 2, b).

In the version of the game with social interaction, additional rules were added to stimulate players to interact and collaborate to obtain more cards. Players can leave one copy of any of their cards, up to Level 2, on each hotspot they visit, once in the morning and once in the afternoon of each day (Figure 2, c). If this happens, that hotspot will be highlighted on other players' devices, with an exclamation mark added to its icon. When a different player visits such hotspot, she receives a copy of the card left there and the original owner also gets more random cards. Every day, players are randomly assigned to a challenge group, and anytime a person in the group collects a card, all other members also receive a card. The members of the group and their contribution to the challenge are shown to all other members to promote a sense of union (Figure 2, d). All players can choose a public avatar and a nickname and can make a short self-introduction; when players receive cards due to other players' actions, they have a chance to give them a "like" (Figure 2, d).

Figure 2. *Screenshots of Shinpo.*

The feasibility study and follow-up evaluations (L. H. O. Santos et al., 2019; L. H. Santos, Okamoto, Funghetto, et al., 2019; L. H. Santos, Okamoto, Hiragi, et al., 2019) suggested that these mechanics allow players to feel more engaged in playing the game by working together with other people. We hypothesized that this setup would result in a higher positive effect on levels of physical activity.

2.1 Experimental Settings

Participants were recruited among community dwelling senior adults living in Kyoto, Japan, and Brasília, Brazil. Because this research is contextualized as a preventive health intervention and it is expected that experience with games will become increasingly common among older adults in the future, the inclusion criteria adopted the broader age range of 50 years or more, aiming for middle-aged and older adults. Additional criteria included healthy people with independent ambulation and no cognitive or physical impairment that prevented them from understanding the instructions of the game or taking short walks. All participants signed an informed consent term, and the research protocol was approved by the respective ethical committees in each country.

A 4-week protocol was adopted. Participants were randomly assigned to either *social interaction* (SI) or *no social interaction* (NSI) groups. During the first week, participants did not play the game, but their level of physical activity, measured by the average number of steps per week, was registered to serve as baseline. During the remaining weeks, participants could freely play the game, while their levels of physical activity and game actions were monitored. Participants were blinded to group assignment, whereas researchers were not.

To evaluate how much participants played the game, the weekly average number of visits to hotspots was also observed. Within a single day, this observation represents the number of unique hotspots visited by the player, while within a week, it is the sum of the visits in each day of the week (i.e., the same hotspot is not counted twice for the same day, but it can be counted twice for a week). Since players were oriented to not keep the game open while walking, so play time was not an appropriate measurement of how much a person played.

At the end of the experiment, participants were asked to answer a survey consisting of the Game Experience Questionnaire (GEQ) (Poels, de Kort, & Ijsselsteijn, 2007) and the System Usability Scale (SUS) (Brooke, 1996). There was also a free text question where participants could write comments, criticism or suggestions. All questionnaires were administered by researchers, who were available to clarify possible doubts about the items.

3. RESULTS

Here we present a summary of the results and data analysis. Section 3.1 reports general information about the participants, Section 3.2 reports the main outcomes and Section 3.3 reports the results of the game experience and usability evaluation.

3.1 Participants

In Table 1, we present a summary of demographic information and data about participants' previous experience with games and technology. The first column shows the grouping item, and the following columns present information about each city, divided by experimental group (SI and NSI). For game experience data, respondents could indicate more than one item and percentages are relative to the number of people who reported any play activity.

Table 1. *Participants' demographic data and previous experience with technology and games.*

Item	Brasília		Kyoto	
	NSI	SI	NSI	SI
Demographics				
Participants (Females)	15 (11)	17 (14)	9 (7)	9 (7)
Average age (σ)	64.3 (6.0)	61.1 (7.4)	62.2 (8.4)	62.2 (8.4)
PC usage frequency				
Everyday (%)	6 (40)	5 (29)	4 (45)	2 (22)
2 or more times/week (%)	4 (27)	4 (24)	1 (11)	2 (22)
Up to once/week (%)	4 (27)	6 (35)	1 (11)	3 (34)
Never (%)	1 (6)	3 (12)	3 (33)	2 (22)
PC skills				
Check email (%)	14 (93)	12 (71)	6 (67)	4 (44)
Online browsing (%)	14 (93)	12(71)	4 (44)	5 (56)
Use social networks (%)	14 (93)	13 (76)	3 (33)	2 (22)
Use applications (%)	7 (47)	4 (24)	5 (56)	5 (56)
Smartphone skills				
Never used (%)	1 (7)	1 (6)	1 (11)	0 (0)
Check email (%)	13 (87)	13 (76)	8 (89)	9 (100)
Online browsing (%)	14 (93)	12 (71)	6 (67)	8 (89)
Use social networks (%)	13 (87)	16 (94)	6 (67)	9 (100)
Install applications (%)	6 (40)	8 (47)	6 (67)	9 (100)
Game play frequency				
Everyday (%)	1 (7)	3 (18)	3 (22)	2 (22)
2 or more times/week (%)	3 (20)	0 (0)	0 (0)	2 (22)
Up to once a week (%)	1 (12)	2 (12)	5 (56)	2 (22)
Never (%)	9 (60)	12 (71)	1 (11)	3 (34)
Play partners				
Alone (%)	4 (67)	4 (80)	8 (100)	6 (100)
Friends (%)	0 (0)	1 (20)	1 (13)	0 (0)
Family (adult) (%)	1 (17)	2 (40)	0 (0)	0 (0)
Family (young) (%)	1 (17)	3 (60)	1 (13)	0 (0)
Strangers (%)	1 (17)	0 (0)	0 (0)	0 (0)

3.2 Physical activity and game interactions

In Table 2, we report the results for the main outcome, with cities side by side. The first column indicates the average value for the baseline (first week), while the following columns indicate the variation in relation to the baseline on each week (weeks 2 to 4). The absolute variation is the difference between the value on the given week and the baseline, for each participant. The relative variation is the ratio between the absolute variation and the baseline, for each participant. Average values and standard errors after calculation are reported in all cases.

We analyzed these results considering the change for each week after baseline to be a repeated measure, and an analysis of variance (ANOVA) was performed, with *group* and *week* as factors. For the results from Brazil, a Type-III strategy was used to account for unbalanced data. Considering the absolute change, the analysis of the effect of *group* as factors resulted in $p = .01$ ($\eta^2 = .19$). No relevant relationship was found with *week* as a factor ($p = .65$). For relative change, taking *group* as a factor resulted in $p = .009$ ($\eta^2 = .27$), while taking *week* as a factor resulted in $p = .54$. For the results from Japan, considering the absolute change, the analysis of the effect of *group* as factors resulted in $p = .04$ ($\eta^2 = .31$). No relevant relationship was found with *week* as a factor ($p = .19$). For relative change, taking *group* as a factor resulted in $p = .02$ ($\eta^2 = .30$), while taking *week* as a factor resulted in $p = .17$.

Table 2. *Average number of steps at baseline and variation in subsequent weeks.*

Group	Measure	Baseline (SE)		Δ_2 (SE)		Δ_3 (SE)		Δ_4 (SE)	
		Brasília	Kyoto	Brasília	Kyoto	Brasília	Kyoto	Brasília	Kyoto
NSI	Absolute	17099.4 (3906.5)	46897.2 (7905.4)	383.8 (563.8)	1583.3 (3108.3)	435.9 (574.5)	591.5 (2414.5)	-106.1 (979.9)	-1041.8 (1992.7)
	Relative	N/A	N/A	1.1% (4.3%)	4.6% (7.2%)	2.2% (4.6%)	2.4% (4.7%)	-2.6% (8.1%)	0.6% (4.4%)
SI	Absolute	17981.9 (2171.1)	45967.3 (8260.7)	3841.9 (1425.4)	11520.0 (3941.5)	2270.6 (947.1)	9576.3 (2631.5)	2443.4 (982.6)	7648.7 (3900.9)
	Relative	N/A	N/A	21.7% (5.1%)	28.0% (8.7%)	16.5% (4.4%)	23.0% (5.1%)	17.9% (4.7%)	13.9% (8.0%)

Data about visits to game locations are shown in Table 3. Each column shows the average number of weekly visits to hotspots for each group in weeks 2 to 4. Standard errors are reported for all values.

Table 3. *Average number of visits to hotspots.*

City	Group	Week 2 (SE)	Week 3 (SE)	Week 4 (SE)
Brasília	NSI	8.4 (2.1)	8.9 (1.7)	5.1 (3.0)
	SI	14.2 (1.9)	9.5 (2.0)	12.8 (3.4)
Kyoto	NSI	42.8 (15.8)	89.7 (24.5)	96.2 (35.2)
	SI	169.0 (63.9)	115.0 (40.0)	140.0 (57.6)

The relationship between the change in the step-count and the number of hotspot visits was evaluated using Pearson's correlation coefficient. For the data from Brazil, the correlation between the absolute change in the number of steps and the number of visits was $r = .21$, with a 95% CI of [-.06, .45]. When relative change was considered, the factor was $r = .34$, with a 95% CI of [.08, 0.56]. For the data from Japan, the correlation between the absolute change in the number of steps and the number of visits was $r = .58$, with a 95% CI of [.32, .77]. When relative change was considered, the factor was $r = .39$, with a 95% CI of [.08, .64].

3.3 Game experience

In Table 4, the scores for the Game Experience Questionnaire and the System Usability Scale are presented. The results of the experiments in Brasília and Kyoto are shown side by side for comparison. Scores range from 0 to 4 and results equal or greater than 2 indicate a strong perception of the item by the user.

Table 4. *Game Experience and Usability questionnaires' comparative results.*

Item	Brasília		Kyoto	
	NSI (SE)	SI (SE)	NSI (SE)	SI (SE)
GEQ – Core				
Competence	N/A	N/A	1.6 (0.1)	2.1 (0.2)
Sensory and Imaginative Immersion	1.8 (0.4)	2.8 (0.2)	1.7 (0.2)	2.3 (0.1)
Flow	N/A	N/A	1.4 (0.2)	1.6 (0.1)
Tension	1.8 (0.3)	0.9 (0.3)	0.5 (0.1)	11 (0.2)
Challenge	1.6 (0.4)	2.0 (0.2)	1.3 (0.2)	1.5 (0.1)
Negative affect	1.3 (0.3)	1.6 (0.3)	0.7 (0.2)	1.0 (0.1)
Positive affect	1.3 (0.2)	2.3 (0.3)	2.6 (0.2)	3.0 (0.1)

GEQ – Social Presence				
Psych. Involvement – Empathy	1.3 (0.5)	1.9 (0.4)	0.8 (0.1)	2.0 (0.2)
Psych. Involvement – Negative	N/A	N/A	0.5 (0.1)	1.0 (0.2)
Behavioral Involvement	1.2 (0.8)	1.0 (0.4)	0.5 (0.1)	1.5 (0.2)
System Usability Scale	2.0 (0.3)	2.4 (0.2)	2.6 (0.1)	2.8 (0.1)

The experiment in Brasília was performed first, and for this experiment the questionnaires were used only as support for initial analysis of the game, so only a subset of the items of the GEQ was included in this experiment. For this reason, it is not possible to draw strong conclusions from this comparison or perform any valid comparative statistical analysis.

4. DISCUSSION

In both experiments, a higher positive effect was observed on the SI group when compared to the NSI group. In the case of Brasília, a statistically significant difference was found only for relative change, not absolute, while a small effect was observed, considering η^2. In the case of Kyoto, however, the difference was significant for both cases, and it also yielded greater effects and higher correlation between play activity and measured effect. This finding leads to the belief that social interaction mechanics had a positive effect on levels of physical activity.

The demographic data does not suggest any significant discrepancy between groups in these two cities, although elderly people in Brazil seem to use the smartphone more often, while elderly people in Japan reported having more experience playing games. One aspect that is relevant for this result is the characteristics of each city. While Brasília is a city with many distant locations that are mainly accessed by car and, to a lesser degree, by public transportation, in Kyoto it is especially common for citizens to walk between destinations on their daily routine. A third possible explanation could be that Japanese people, in general, have higher baseline levels of physical activity, when compared to Brazilian people (Aoyagi & Shephard, 2010; Guedes, Hatmann, Martini, Borges, & Bernardelli, 2012).

Another observed discrepancy rested in the number of game interactions in each experiment, with values in Japan reaching as much as 10 times those observed in Brazil. This could have happened due to the fact that basic searches for religious building (shrines and temples) in Kyoto can easily return dozens of results for any given part of the city, while in Brazil the hotspots would be based more on different keywords, such as parks and public squares, due to the specific context of each case. It could also be the case that in Japan elderly people felt more motivated to visit many places, due to a deeper connection with the topic of shrines and temples for these participants than Brazilian participants would feel with the more generic categories used in their case.

The usability of the system seems adequate all cases, since values equal or greater than 2 were obtained for all groups. For the game experience, the items "Sensory and Imaginative Immersion" and "Positive Affect" had particularly higher values in the SI groups, which could be explained by the naturally higher level of immersion of pervasive games, which also causes an overall better experience for the player. However, since positive evaluations were observed only for the SI groups, it seems that the social element is important for this result. It is interesting to notice that the results of the experience evaluation were larger for the SI group for all 2 categories, in Brazil, and all in Japan, suggesting more social interaction in that group, both positive and negative. For the core items of GEQ, the SI group had better results than NSI group for "Positive Affect", "Competence" and "Sensory and Imaginative Immersion", but "Challenge", "Negative Affect" and "Tension" were also higher, although not over 2, which would be a bad result overall. This would suggest that people in this group had a more intense game experience.

The self-reported evaluation given on the free text comments seems to indicate that players in the SI groups in both cities had more fun and felt more engaged in the game, specifically enjoying the card exchange mechanics, although they also felt motivated by the chance of being stimulated to exercise more. Participants from both cities in all groups complained about the lack of competition, which is a modality of social interaction, leading to the belief that the social factor is relevant for some players.

Despite these differences, the results of both experiments line up to give stronger evidence that social interaction is an important motivational factor into promoting physical activity of elderly people using pervasive games.

4.1 Limitations

The studies described here had the following limitations.

The sample size was small, which reduces the possibility of observing stronger (or weaker) effects and gathering more insights about the experience of players. The main outcome was measured using a smartphone software. The methodology has been evaluated in previous studies, and the authors of those studies concluded that it is adequate; however, future interventions might test similar settings with a different device, such as external pedometers, and compare the results. In both cases, because the data are not collected in a controlled environment but rather in a user-dependent context, participant compliance with carrying the device affects the results. Also, step-counts were observed in a continuous state, considering any daily activity of participants. Because the baseline week used these same criteria and the analysis considered the observed change, the results are still relevant. Nonetheless, further interventions might also separate in-game counts explicitly and analyze if there is any difference. Finally, although this research is inserted in the more general field of interventions to improve the quality of life of older adults, it focuses specifically on increasing physical activity based on previous results that show a strong correlation between these variables. Future interventions could measure these two variables explicitly and evaluate their relationship in the context of pervasive games.

5. CONCLUSION

Although previous studies had already found a strong connection between social interaction and the quality of life of the elderly, in this study we found that social interaction is an important design element also on pervasive games targeting the elderly. In our findings, we could see an effect of this element on player behavior and on their experience while playing, and our game had successfully generated a positive effect on elderly players. We observed a significant increase on physical activity, which is another key factor for the quality of life of the elderly.

Next steps of this research could include a deeper investigation of how social interaction affects the gameplay. For instance, other modalities of social interaction, such as competition and a combination of competition and collaboration could be explored. Additionally, mechanisms for players to get more personally involved in game could be created, such as collaborative creation of narratives inside the game, or ways for player to create connections with the places they visit and/or with other players.

Acknowledgements: This study was partially supported by the Hayao Nakayama Foundation for Science & Technology and Culture, by Kyoto University's Collaborative Graduate Program in Design, and by the Japan Society for Promotion of Science's KAKENHI, grant number 19K12820. The authors thank the participants for volunteering and the students and staff for helping to conduct the experiments.

6. REFERENCES

Aoyagi, Y., & Shephard, R. J. (2010). Habitual physical activity and health in the elderly: The Nakanojo Study. *Geriatrics & Gerontology International*, *10*(SUPPL. 1), S236–S243. https://doi.org/10.1111/j.1447-0594.2010.00589.x

Bleakley, C. M., Charles, D., Porter-Armstrong, A., McNeill, M. D. J., McDonough, S. M., & McCormack, B. (2015). Gaming for health: a systematic review of the physical and cognitive effects of interactive computer games in older adults. *Journal of Applied Gerontology*, *34*(3), NP166–NP189. https://doi.org/10.1177/0733464812470747

Brooke, J. (1996). SUS - A quick and dirty usability scale. In *Usability Evaluation in Industry* (Vol. 189, pp. 4–7).

Carvalho, R. N. S. De, & Ishitani, L. (2012). Motivational Factors for Mobile Serious Games for Elderly Users. In *Brazilian Symposium on Games and Digital Entertainment* (pp. 19–28). Brasília, DF, Brazil: SBC.

Case, M. A., Burwick, H. A., Volpp, K. G., & Patel, M. S. (2015). Accuracy of Smartphone Applications and Wearable Devices for Tracking Physical Activity Data. *JAMA*, *313*(6), 625. https://doi.org/10.1001/jama.2014.17841

Cota, T. T., Ishitani, L., & Vieira, N. (2015). Mobile game design for the elderly: A study with focus on the motivation to play. *Computers in Human Behavior*, *51*, 96–105. https://doi.org/10.1016/j.chb.2015.04.026

De Schutter, B. (2011). Never Too Old to Play: The Appeal of Digital Games to an Older Audience. *Games and*

Culture, *6*(2), 155–170. https://doi.org/10.1177/1555412010364978

De Schutter, B., & Malliet, S. (2014). The older player of digital games: A classification based on perceived need satisfaction. *Communications*, *39*(1), 67–88. https://doi.org/10.1515/commun-2014-0005

Guedes, D. P., Hatmann, A. C., Martini, F. A. N., Borges, M. B., & Bernardelli, R. (2012). Quality of Life and Physical Activity in a Sample of Brazilian Older Adults. *Journal of Aging and Health*, *24*(2), 212–226. https://doi.org/10.1177/0898264311410693

Guo, H., Trætte, H., Wang, A. I., & Zhu, M. (2010). TeMPS: A Conceptual Framework for Pervasive and Social Games. *2010 Third IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning*, 31–37. https://doi.org/10.1109/DIGITEL.2010.40

Hagan, R., Manktelow, R., Taylor, B. J., & Mallett, J. (2014). Reducing loneliness amongst older people: a systematic search and narrative review. *Aging & Mental Health*, *18*(6), 683–693. https://doi.org/10.1080/13607863.2013.875122

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *The Lancet*, *380*(9838), 247–257. https://doi.org/10.1016/S0140-6736(12)60646-1

Kay, T., Daykin, N., Lane, J., Meads, C., & Studies, A. (2018). An overview of reviews: the effectiveness of interventions to address loneliness at all stages of the, (October), 1–87. Retrieved from https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=97293

Larsen, L. H., Schou, L., Lund, H. H., & Langberg, H. (2013). The Physical Effect of Exergames in Healthy Elderly—A Systematic Review. *Games for Health Journal*, *2*(4), 205–212. https://doi.org/10.1089/g4h.2013.0036

Marquet, O., Alberico, C., Adlakha, D., & Hipp, J. A. (2017). Examining Motivations to Play Pokémon GO and Their Influence on Perceived Outcomes and Physical Activity. *JMIR Serious Games*, *5*(4), e21. https://doi.org/10.2196/games.8048

McLaughlin, A., Gandy, M., Allaire, J., & Whitlock, L. (2012). Putting Fun into Video Games for Older Adults. *Ergonomics in Design: The Quarterly of Human Factors Applications*, *20*(2), 13–22. https://doi.org/10.1177/1064804611435654

Montola, M. (2005). Exploring the edge of the magic circle: Defining pervasive games. *Proceedings of DAC*, *1966*, 16–19. https://doi.org/10.1.1.125.8421

Niantic, L. (2016). Pokemon GO. Retrieved from https://play.google.com/store/apps/details?id=com.nianticlabs.pokemongo. Accessed: 2017-11-14. (Archived by WebCite® at http://www.webcitation.org/6uywbsV3m)

Poels, K., de Kort, Y. A. W., & Ijsselsteijn, W. A. (2007). *D3.3 : Game Experience Questionnaire*. Eindhoven.

Romeo, A., Edney, S., Plotnikoff, R., Curtis, R., Ryan, J., Sanders, I., … Maher, C. (2019). Can Smartphone Apps Increase Physical Activity? Systematic Review and Meta-Analysis. *Journal of Medical Internet Research*, *21*(3), e12053. https://doi.org/10.2196/12053

Santos, L. H. O., Okamoto, K., Hiragi, S., Yamamoto, G., Sugiyama, O., Aoyama, T., & Kuroda, T. (2019). Design Elements of Pervasive Games for Elderly Players: A Social Interaction Study Case. In *Human Aspects of IT for the Aged Population. Applications in Health, Assistance, and Entertainment* (pp. 204–215). https://doi.org/10.1007/978-3-030-22015-0_16

Santos, L. H., Okamoto, K., Funghetto, S. S., Cavalli, A. S., Hiragi, S., Yamamoto, G., … Kuroda, T. (2019). Effects of Social Interaction Mechanics in Pervasive Games on the Physical Activity Levels of Older Adults: Quasi-Experimental Study. *JMIR Serious Games*, *7*(3), e13962. https://doi.org/10.2196/13962

Santos, L. H., Okamoto, K., Hiragi, S., Yamamoto, G., Sugiyama, O., Aoyama, T., & Kuroda, T. (2019). Pervasive game design to evaluate social interaction effects on levels of physical activity among older adults. *Journal of Rehabilitation and Assistive Technologies Engineering*, *6*, 205566831984444. https://doi.org/10.1177/2055668319844443

Vagetti, G. C., Barbosa Filho, V. C., Moreira, N. B., Oliveira, V. de, Mazzardo, O., & Campos, W. de. (2014). Association between physical activity and quality of life in the elderly: a systematic review, 2000-2012. *Revista Brasileira de Psiquiatria*, *36*(1), 76–88. https://doi.org/10.1590/1516-4446-2012-0895

A Virtual Reality Bus Ride as an Ecologically Valid Assessment of Balance: A Feasibility Study

A R Gonçalves[1], M F Montoya[2], R Llorens[3], S Bermúdez i Badia[4]

[1,4]Madeira-ITI & Faculdade de Ciências Exatas e da Engenharia, Universidade da Madeira,
Funchal, PORTUGAL

[1,4]NOVA LINCS, Universidade Nova de Lisboa,
Caparica, PORTUGAL

[2]Human-Computer Interaction Group, Universidad Tecnológica de Pereira,
Pereira, COLOMBIA

[3] Neurorehabilitation and Brain Research Group, Universitat Politècnica de València,
Valencia, SPAIN

[1]*afonso.goncalves@m-iti.org*, [2]*mf.mv@utp.edu.co*, [3]*rllorens@i3b.upv.es*, [4]*sergi.bermudez@m-iti.org*

ABSTRACT

Balance disorders can lead to severe consequences for older adults. Computerized posturography offers an objective assessment of balance, and VR can help to increase its ecological validity. We investigate to what extent a posturographic VR bus ride is ecologically valid and suitable to assess balance. Sixteen healthy adult participants underwent the VR bus ride. Participants felt a moderate level of presence, and the simulation elicited significant postural changes responses, which correlated with validated posturography assessments of the participants. The results support the viability of our tool for balance assessment in the context of a meaningful activity.

1. INTRODUCTION

Balance disorders or problems maintaining postural balance can have substantial implications on the performance of most daily activities and lead to an increased risk of falls, which often have severe consequences for older adults (Salzman, 2010). However, for community-dwelling older adults, most of the research-based assessments are abstract single-tasks evaluations that do not feature a representative design of functional activities, and there is a need for items that better reflect postural control demands in daily-life situations (Pardasaney et al., 2013). There is a lack of ecological validity that can hinder the transferability of results to real-world situations for which virtual reality (VR) could provide a solution. To design a digital system that could overcome the limitation in the transferability of older adults posturography results to real-world situations, we developed the "VR Bus Assessment of Balance." A dynamic posturography test that introduces optical-flow perturbations in a realistic and ecological valid task. This work represents a feasibility study, done with healthy adults, where we investigate to what extent this simulation is suitable to assess balance by comparing it against a validated posturography tool. First, we measured how much participants felt present in the simulated world, thus increasing the ecological validity of the tool. Then, we investigated if this tool could produce observable and significant changes in participants' posture, measured trough centre-of-pressure (CoP) position. Lastly, we followed up on the previous question and examined if there were significant correlations between the participants' responses to our VR simulation and their ability to keep balance.

2. METHODS

The VR Bus Assessment of Balance, a virtual bus ride, was built with the game engine Unity 3D. The backdrop of the ride are the virtual streets of Reh@City, a grid plan neighbourhood of a city with over 200 buildings (Teresa

Paulino, Ana Faria and Sergi Bermudez i Badia, 2019). The bus drives a closed circuit with realistic behaviour, which lasts approximately 4.5 minutes to complete. The experience takes place inside a CAVE, mediated through the KAVE software (Gonçalves and Bermúdez, 2018). During the virtual ride, data are collected from the virtual bus itself (position and orientation) and a Wii Balance Board (WBB) (CoP position over the board).

Participants had their balance and postural control assessed with a validated WBB-based posturography system (Llorens et al., 2016). After that, they completed the VR bus ride, acting as a standing bus passenger over the WBB, facing the front wall of the CAVE. Lastly, answered the Slater-Usoh-Steed Questionnaire (SUS) (Slater et al., 1995), and the Presence Questionnaire (PQ) (Witmer et al., 2005).

3. RESULTS & DISCUSSION

Participants reported moderate levels of presence, comparable to other VR experiments with the same system. The immersive characteristics of the VR system contributed positively to presence, while the lack of interaction had a negative effect. Statistical testing revealed significant differences in posturographic measurements between different segments of the ride. Segments in which the bus turns, significantly increased maximum CoP excursion in the medial-lateral axis and CoP mean speed, relatively to straight segments. It made them adopt an anticipatory compensation behaviour when subjected to variations of the visual stimuli. This tells us that the VR bus ride can be used to trigger balance control responses successfully. Lastly, participants' CoP excursions during the static posturography assessment correlated negatively with medial-lateral excursions in the VR ride, that presented them with visual information contrary to vestibular. This finding suggests that the VR Bus Assessment of Balance is sensitive to detect people with a lower visual information weight when integrating it with somatosensory and vestibular information for balance and postural control.

4. CONCLUSIONS

Our study supports the feasibility of our paradigm to assess balance based on a more ecologically valid scenario, contextualized by a meaningful activity of daily living. Following this feasibility study, the system will be re-evaluated to assess its discriminative properties in older adults with an increased risk of falls.

7. REFERENCES

Gonçalves, A., Bermúdez, S., 2018. KAVE: Building Kinect Based CAVE Automatic Virtual Environments, Methods for Surround-Screen Projection Management, Motion Parallax and Full-Body Interaction Support. Proc ACM Hum-Comput Interact 2, 10:1–10:15. https://doi.org/10.1145/3229092

Llorens, R., Latorre, J., Noé, E., Keshner, E.A., 2016. Posturography using the Wii Balance Board™: A feasibility study with healthy adults and adults post-stroke. Gait Posture 43, 228–232. https://doi.org/10.1016/j.gaitpost.2015.10.002

Pardasaney, P.K., Slavin, M.D., Wagenaar, R.C., Latham, N.K., Ni, P., Jette, A.M., 2013. Conceptual Limitations of Balance Measures for Community-Dwelling Older Adults. Phys. Ther. 93, 1351–1368. https://doi.org/10.2522/ptj.20130028

Salzman, B., 2010. Gait and Balance Disorders in Older Adults. Am. Fam. Physician 82, 61–68.

Slater, M., Steed, A., Usoh, M., 1995. The Virtual Treadmill: A Naturalistic Metaphor for Navigation in Immersive Virtual Environments, in: Virtual Environments '95, Eurographics. Springer, Vienna, pp. 135–148. https://doi.org/10.1007/978-3-7091-9433-1_12

Teresa Paulino, Ana Faria and Sergi Bermudez i Badia, 2019. Reh@City v2.0: a comprehensive virtual reality cognitive training system based on personalized and adaptive simulations of activities of daily living. Presented at the The Experiment@ International Conference 2019 (exp.at'19), IEEE, Funchal, Portugal.

Witmer, B.G., Jerome, C.J., Singer, M.J., 2005. The Factor Structure of the Presence Questionnaire. Presence Teleoperators Virtual Environ. 14, 298–312. https://doi.org/10.1162/105474605323384654

The design of a fully immersive virtual reality application for upper limb rehabilitation post-stroke using mirror therapy

S M Leniston-Kahsai[1], Dr E R Rodríguez Ramírez[2], Dr Brian Robinson[3], Dr N Signal[4], Byron Mallett[5]

[1,2,5]School of Design Innovation, Victoria University of Wellington,

39 Vivian Street, Te Aro, Wellington, NEW ZEALAND

[3]School of Nursing, Midwifery and Health Practice, Victoria University of Wellington,

Level 7 & 8, Clinical Services Building, Wellington Regional Hospital, Wellington, NEW ZEALAND

[4]School of Clinical Sciences, Auckland University of Technology,

90 Akoranga Drive, Northcote, Auckland, NEW ZEALAND

[1]*lenistsena@myvuw.ac.nz*, [2]*edgar.rodriguez@vuw.ac.nz*, [3]*brian.robinson@vuw.ac.nz*, [4]*nada.signal@aut.ac.nz*

[1, 2, 3]*www.wgtn.ac.nz*, [4]*www.aut.co.nz*

ABSTRACT

The research project involved the design of fully immersive virtual reality (VR) application based on mirror therapy (MT). VR, in combination with interactive gaming, affords opportunities to extend the visual and proprioceptive feedback employed in MT and facilitate engagement to participate in rehabilitation. The research project comprised three stages: data collection through a design thinking workshop with clinicians, engineers, and people with stroke (PwS), iterative design and prototyping of a VR game based on the design requirements and expert review of designs with clinicians. The VR application was developed and designed according to design criteria from the primary research conducted at the workshop. The prototype could form the basis for an application that may be used by PwS to support their ongoing upper limb rehabilitation. Future directions will include testing how VR could facilitate engagement in rehabilitation through qualitative analysis of user testing phase with PwS.

1. INTRODUCTION

Mirror therapy (MT) is a low-cost intervention that uses a simple visual illusion to promote motor recovery during stroke. The subject views the reflection of their non-paretic limb performing exercises in a mirror, while their paretic limb is blocked from view behind the mirror, to trick their brain into thinking their paretic limb is moving symmetrically and synchronously with their non-paretic limb (Deconinck et al., 2015). This simple visual illusion capitalises on the brain's preference for visual feedback over proprioceptive and somatosensory feedback about limb position in space. Motor priming techniques activate brain regions involved in motor planning and intention to move, to prime the primary cortex, therefore facilitating motor learning and reducing impairment by inducing neuroplasticity (Stoykov & Madhavan, 2015). Meta-analysis of MT has been conducted highlighting the efficacy of MT for improving motor function after stroke (Thieme et al., 2018) when used as an adjunct coupled with conventional physical therapy when the patient is unable to fully use their paretic upper limb.

Immersive virtual reality (VR) technology provides a solution to enhance the illusion utilised in MT by overcoming the spatial and creative limitations of the conventional mirror box. Head Mounted Displays (HMDs) afford immersion to be increased beyond the conventional mirror box through the creation of virtual environments and virtual representations of the body, which are not physically constrained in the physical world, extending the types of exercises and movements that are possible. Meta-analysis on mostly non-immersive VR for stroke rehabilitation showed that VR is no more effective than conventional rehabilitation in terms of functional outcomes when conducted in isolation (Laver et al., 2017). However, they also showed a statistically significant benefit when VR is used as an adjunct to conventional rehabilitation. There was also no subgroup analysis conducted on non-immersive versus fully immersive VR due to the limited number of fully immersive solutions (Laver et al., 2017, p. 25). Therefore, there is debate on whether VR-based mirror therapy provides enough value over conventional mirror therapy to justify the cost and technical requirements of VR (Darbois et al., 2018).

People with stroke (PwS) are also not engaging in a sufficient dose of therapy to induce significant neuroplastic changes. Lang et al. (2009) conducted an observational study of 312 physical and occupational therapy sessions for PwS at inpatient and outpatient settings and recorded movement practice and number of repetitions. They found the amount of motor practice provided during practice was insufficient to drive neuroplasticity and promote optimal recovery of motor function. Adherence to post-stroke rehabilitation at home after discharge from a rehabilitation clinic has also shown to be low. The most common reasons for non-adherence were identified as doing different exercises to those prescribed and that exercises were painful or boring (Miller et al., 2017). However, very few studies report on why PwS would find therapy "boring" or how can we design to avoid such boredom. Purpose-built video games could use elements of effective stroke rehabilitation like task-specific training required for recovery of function, while also increasing therapy dose through engagement (Lohse et al., 2013). Therefore, to design VR experiences to increase engagement, we need to understand the daily life of PwS through their rehabilitation journey to help us identify opportunities to facilitate therapy dose and engagement.

We propose to design and develop a purpose-built fully immersive VR application based on mirror therapy as a support tool for upper limb rehabilitation. We aimed to construct themes for the VR game by consulting PwS and stroke rehabilitation experts through a design thinking workshop. We developed design criteria from these themes and investigated the usability of the game as well as how the design of the game met our design criteria by validating the application with clinicians. In this paper, we discuss the data collection phase, the prototyping phase, the results of an expert review of designs and final conclusions.

2. DESIGN THINKING WORKSHOP

Using human-centred design, in collaboration with the Auckland University of Technology Health and Rehabilitation Research Institute (AUT HRRI), we conducted a workshop with PwS (n = 4) and experts (n = 5 clinicians and n = 4 engineers) to identify their needs and interests to engage with games and devices to support stroke rehabilitation. The goals of this workshop were to develop a common understanding of first-hand attitudes, experiences, and expectations of applications and devices for stroke rehabilitation and to develop design criteria and the user journey for a VR system to facilitate stroke rehabilitation at home.

2.1 Participants

Thirteen participants were recruited. Four PwS were at the chronic stage (> 6 months post-stroke), 5 clinicians were physiotherapists with expertise in stroke rehabilitation and research and 4 engineers with expertise in developing devices and games for stroke rehabilitation. Engineers were present as part of a separate research project investigating the acceptability of a robotic device for upper limb stroke rehabilitation. We had ethics approval from the Human Ethics Committee at Victoria University of Wellington (Ref: 0000027728).

2.2 Design Thinking Activities

Participants were split into 3 groups each consisting of at least one PwS, one clinician, one engineer and a designer facilitating the activities. User journey maps were used to gain an understanding into how stroke rehabilitation was incorporated into everyday life of PwS (Endmann & Keßner, 2016). Empathy maps and card sorts were used to gain insight about what mattered most to the target audience (Ferreira et al., 2015). Finally, mood boards were used to ascertain the visual qualities and the types of games that appealed to the target audience (Cassidy, 2011). The qualitative data was analysed through thematic analysis to construct themes.

2.3 User Journey

We asked participants to map out a user journey map in terms of when they did rehabilitative exercise, when they had leisure time and finally when they took part in a hobby during a typical day. We asked PwS to use their own personal experience and asked clinicians and engineers to utilise modified user personas for a motivated and unmotivated PwS (Pyae et al., 2013). User personas provide meaningful archetypes of people based on collective research which can be used to assess designs against (Martin & Hanington, 2012). Participants indicated the duration of time spent, location, and variables which initiate/motivate or stop/inhibit the activity.

2.3.2 Motivators and inhibitors of rehabilitation. The responses showed that rehabilitation occurred more than twice as much at home than at the gym and clinic. This highlights the importance of designing the application to integrate within the home environment. PwS and experts reported the 'self' as a key motivator for rehabilitation (42% and 52% of responses respectively), while PwS saw clinicians as a motivator (25%), compared to experts who saw clinicians as less of a motivator (12%). The findings indicate that clinicians must be involved in the use of any adjunctive tool to provide validation and motivate PwS to engage with it. Positive feedback and encouragement from therapists help PwS gain confidence that they are completing exercises correctly and to ensure they are making progress (Pyae et al., 2015, p. 103).

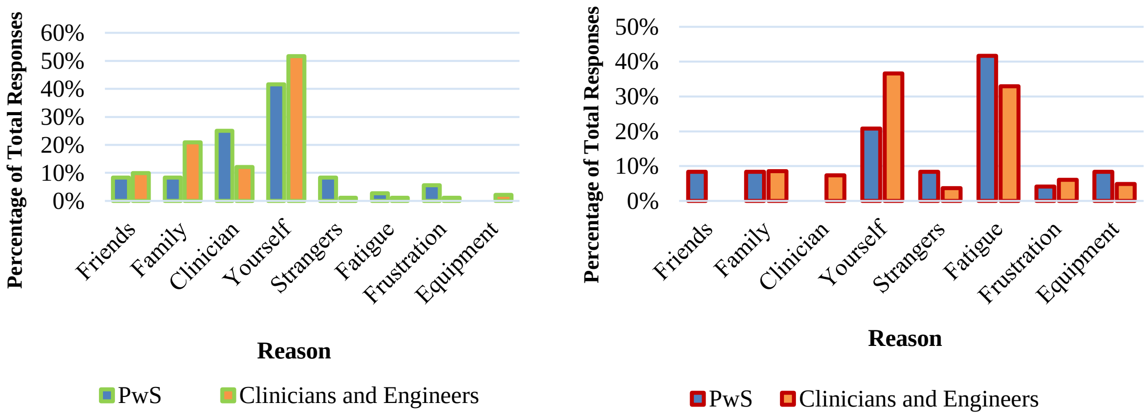


Figure 1. *(a) Main motivators for all activities for PwS (N = 36 responses) and experts using personas (N = 91 responses), (b) Main inhibitors for all activities for PwS (N = 24 responses) and experts using personas (N = 82 responses)*

Fatigue was the key inhibitor of rehabilitation for both PwS and experts (42% and 36% respectively) while experts saw the 'self' as an inhibitor (39%) compared to PwS (21%). Self-efficacy to start an activity is key, which aligns with the concept of intrinsic motivation. However, almost equally important are external motivators including clinicians and family members. Therefore, a design opportunity for the VR game is to involve clinicians and family members in initiation of using the game. The 'self' was also identified as a factor to stop a rehabilitation session along with fatigue. For rehabilitation, it is key to increase physical activity and cognitive stimulation but to limit physical and mental fatigue (Gordon et al., 2004). Therefore, the game should target physical exertion through repetitions without inducing cognitive overload.

2.4 Thematic analysis

Five key themes were constructed from the workshop activities and discussions following thematic analysis of the data. These themes and associated evidence from the workshop are discussed below:

2.4.1 Accessibility and simplicity. Participants wanted "something that's relatable and that seems achievable". Games and devices should be designed for ease of use and minimal setup time. Clinicians want was flexible to their patients as they progress. A clinician stated that a device "would have to be kind of iterative in a sense. That it could change for [them] over time". The more flexible our system is the more likely people will engage with it.

2.4.2 Communication and Feedback. Most participants see empathy as a key feature of positive clinical care. A clinician recounted they were "relieved [they] were heard and understood. Confident that care plan was robust. Empowered with new plan and info to deal with the situation". Clear communication and empathy can empower people towards informed decisions about their healthcare. A participant stated that "[they'd] have felt more supported through more information". Therefore, feedback should be catered to one's needs. A clinician stated that a key feature of good health care was "getting the information when you want, at the level you want at the time you want". Therefore, our game should provide meaningful, relevant, and timely feedback to PwS.

2.4.3 Engagement. Engagement leads to participation in the process of recovery and rehabilitation. A person with stroke recalled that rehabilitation classes "made her happy because she was doing something about her rehabilitation and said that it made [her] feel good when [she] was engaging in it". PwS said they compared themselves to others to gauge their own level of function. This seemed to help the PwS value their own progress and motivate themselves to work harder as one person with stroke stated that they are "quite competitive" in group stroke therapy. This may provide a design opportunity where healthy competition in a group environment may help PwS motivate each other.

2.4.4 Progress. One person with stroke was concerned that "it took a long time to see big improvements in her rehab". Participants may feel they have an expectation to progress at an unattainable pace. They want to "get back to what [they were] doing before", "become good again", "without loss of condition". Participants wanted to be challenged but they also wanted to be paced correctly and set goals. One participant stated that "[they] think [they] want to be able to move with the experience. With the full journey to get the most benefit". This shows the importance of adapting and setting goals throughout the process. This provides a design opportunity for creating a tool that can be used at home, is always accessible and provides realistic goals to achieve.

2.4.5 Social connection and wellbeing. A person with stroke recounted that "[they were] with a group of people that knew what [they] was going through", highlighting the importance of shared experiences and relationships. A clinician questioned "whether what [we're] trying to do with this technology is replace [their] relationship that [they] have had with this person [they] have been working with for months". Therefore, tools must be designed to support clinicians, not replace them. A person with stroke reflected that "the therapies, programmes could help me to find the positive and have wellbeing again". Our game should provide positive reinforcement through game design.

2.4 Design Criteria

Design criteria are used to assess designs in a systematic way without compromising creative freedom (Rodríguez Ramírez, 2017). The following table outlines the design criteria from the workshop:

Table 1. *Design criteria for immersive virtual reality application for upper limb stroke rehabilitation*

Theme	Subthemes	Design solutions
Accessibility and simplicity	• Easy to understand • Can be played regularly without inducing mental fatigue or cognitive overload • Provide options to users to tailor and customise their experience	• Tutorialisation of gameplay • Task variety with simple mechanics • Customisation options for game avatar e.g. skin tone
Communication and feedback	• Clear communication of performance in the game is provided • Coherency between games, tasks, and exercises • Movement visualization in the virtual world must match real world movements	• Tracking and recording position of both hands • Games based on functional tasks
Engagement	• Leverage gamification to make repetitive exercise fun • Games are designed to balance challenge and skill to increase engagement • Interactions feel natural and based on real world interactions	• Games are designed to maximise repetitions in engaging tasks • Interactions are grounded in functional tasks
Social connection and wellbeing	• Positive reinforcement • Involvement of support network (clinicians, family and friends) • Virtual environments that facilitate positive wellbeing	• Clinicians and carers play active role in use • Outdoor setting is relatable and aids wellbeing
Progress	• Reward successful movements • Transfer of learned behaviour into the real world • Adapt difficulty and challenge to the user	• Scoring system to record and incentivise success • Adaptive difficulty settings

3. INITIAL PROTOTYPE

We developed a prototype VR game using Unity game engine and a commercially available VR headset, the Oculus Quest (Oculus VR, Menlo Park, CA), with two controllers, which capture hand motions and provide buttons for user input. All tasks are designed to be carried out with the unaffected hand to provide accessibility for users with severe impairment of one limb. This game requires being seated in front of a table to provide a point of reference within the virtual environment to minimise motion sickness and ensure safety. Players use one controller positioned in their unaffected hand and fastened to the palm. The player visualises a mirrored representation of their unaffected hand movements superimposed onto a virtual representation of their affected hand (Figure 2a). Players complete all tasks using their unaffected limb and maintain their affected limb resting on the table. The system captures and portrays movement of a virtual hand at the wrist. Finger movements as the player grasps and releases the trigger buttons are translated to animations of the virtual fingers. We record elevation of each hand from the table in centimetres in real-time. The three major components of the prototype are outlined below.

3.1 Tutorial and Setup Level

Tutorialisation is the teaching of game mechanics and controls required to successfully play the game. The tutorial was based on the built-in tutorial on the Oculus Quest to provide familiarity to the player. The tutorial consisted of setting up the user profile including gender, affected side, table height and skin colour. This allows the user to familiarise themselves with the user interface and controller. The second part involves the visualisation of mirror therapy and completion of a functional reach-and-grasp task using the mirrored hand. Players are tasked to grab a log of wood, chop it with an axe and place the chopped log on the campfire to start the fire (Figure 2b).

Figure 2. *(a) Third person view of VR environment showing unaffected right limb driving a mirrored virtual affected left limb, (b) First person view of reach-and-grasp task and controller instructions.*

3.2 Competitive Game: Wasp Attack

The competitive game is a reach-to-target task called ‘Wasp Attack’. This task focuses on gross motor movements at the shoulder. The player must hit gold and blue wasps that appear at one of four heights in time to music. Wasps are coloured corresponding to the colour of the hand used to hit the wasp, gold on the left hand, and blue on the right. Every time the player hits a correct wasp, they get a point and the controller provides haptic feedback to both hands. In the tutorial level the player is tasked with hitting 30 wasps before time runs out. If they miss 20 wasps, they restart the level. The levels of this game can progress to incorporate varied movements of the shoulder by varying the wasp placement as the player progresses through the levels.

Figure 3. *(a) Third person view of VR environment showing unaffected right limb driving a mirrored virtual affected left limb to hit a gold wasp, (b) First person view of reach-to-target task.*

3.3 *Non-Competitive Game: Art Camp*

The non-competitive game is an unguided art therapy-based game called ‘Art Camp’. Art therapy was chosen for the non-competitive task due to its accessibility for a wide range of people and levels of impairments. Other proposed benefits of art therapy have been shown to include alleviating stress and promoting wellbeing (Reynolds, 2012). In the game players can create 3D drawings using the non-affected hand while their mirrored hand will draw symmetrically and synchronously across the sagittal plane. Players can edit drawings as well as change colours and brush tools using a physical palette interface on the table.

Figure 4. *(a) Third person view of VR environment showing the unaffected right limb driving a mirrored virtual affected left limb to draw, (b) First person view showing symmetrical drawing.*

4. EXPERT REVIEW

We conducted expert reviews with 4 physiotherapists and 2 occupational therapists (n=6). An expert review is conducted by a representative user to identify possible issues with the user interface of a design. The protocol involved the design researcher playing the VR game and streaming gameplay live via video conferencing software in a first-person view and third person view using a mixed reality setup using LIV mixed reality software (LIV Inc., Prague) (Figure 5). Feedback from clinicians generated iterative changes to the software to be tested further in follow up research. A System Usability Scale was conducted post-test to assess usability of the system.

Figure 5. *Clinicians could view game in third person (current main view) or first person (bottom right view). Head camera (bottom left) provided unobstructed view of arm movements.*

4.1 *Clinician Feedback*

The following highlights the key discussion points following expert review against the design criteria:

- *Accessibility and simplicity*. Overall, clinicians could follow the setup process, however they suggested to continue to simplify the instructions to be more accessible and directive. Most clinicians felt that these technologies would be best suited for the next generation of PwS who are more technologically inclined. They appreciated that the design of the game made it accessible to a wide variety of motor impairments. However, for clinicians to be onboard the technology must be simple to learn setup and use. The clinicians liked the outdoor campsite setting and felt that the environment would be relatable and engaging for their clients. However, they unanimously felt the environment was too complex in its current state. They worried that if it is too visually stimulating it may be distracting or induce mental fatigue. They felt that simplifying the environmental complexity would not reduce the level of immersion in the experience.

- *Communication and feedback*. All clinicians liked that participant performance was recorded through scoring and tracking position of the players limbs. The clinicians felt limb elevation was useful information to show progress, however they felt it should be reserved for an end of level report so as not to overwhelm people with information during play as they will likely focus on their score. Clinicians also liked that we provided haptic vibration feedback to the affected hand in the 'Wasp Attack' game.
- *Engagement*. The clinicians felt that VR could be empowering and self-motivating in a home setting. The clinicians liked the idea of using mirror therapy to get participants familiar with VR before incorporating their affected arm and felt that "opens it up for a lot of people". They also felt that this implementation of mirror therapy provided more flexibility than the limited movements available with the conventional mirror box. One clinician suggested the visual illusion could be enhanced by having a full arm visualised. We have experimented with using inverse kinematics to have full body representation and have included this in recent updates to allow visualisation of the shoulder and elbow to enhance the illusion.
- *Progress*. The clinicians wanted more repetition of tasks during the tutorial. One clinician suggested that reach-and-grasp tasks during the tutorial could be introduced as a separate activity due to its complexity and the importance of reach-and-grasp movements. A few clinicians suggested that functional tasks related to activities of daily living could be included and be suited in the context of the camp setting.
- *Social connection and wellbeing*. The clinicians admitted there needs to be "generational and systemic change" before VR is accepted but appreciated that tools like this would be a great home program for self-directed rehabilitation. The art therapy game was appreciated for its contrast to other tasks and its ability to stimulate creativity. One clinician suggested having multiple players for example, a grandchild or carer could play along with the game on an external device to facilitate intergenerational play.

Clinician perceptions of the application's potential usability were recorded using the System Usability Scale (SUS). Scores ranged from 48 to 83, with a mean of 67 and a median of 66. Scores above 68 on this scale are classified as above average usability. Once iterations have been made to accommodate their recommendations it is anticipated that a retest would lead to an increase in SUS score.

5. CONCLUSIONS

The findings from this usability study suggests that there is interest with clinicians in using immersive VR-based mirror therapy as an adjunct to conventional rehabilitation. Due to the limited sample size and the nature of the remote testing the results should be interpreted with caution. We will be able to reach more informed conclusions about usability when the application is tested with PwS. A pilot study showed that an immersive VR mirror therapy intervention, similar to the one used in this study, was well tolerated by PwS in the chronic stage in terms of usability and symptoms of motion sickness (Weber et al., 2019). Therefore, there is scope for our game to be safely tolerated by PwS. Immersive VR therapy could be coupled with conventional rehabilitation to increase therapy dose and efficacy, which has been shown with the use of conventional mirror therapy as an adjunct to increase motor outcomes (Laver et al., 2017). In our application, although the affected arm is resting on the table, we always track the position of the affected arm in the background. Weber et al. (2019) observed unintended movement of the affected arm to match the mirrored virtual representation even when subjects were asked to maintain their affected arm at rest. In our application we could measure these nonvolitional movements and use this data to grade the range of movement of their affected limb. Therefore, in future studies there is potential for the application to encourage more movement of the affected limb over mirror therapy as the PwS progresses. In conclusion, we have explored how the design of a VR game can incorporate themes relevant to the target audience. Future directions will include testing how the application increases motivation and engagement in rehabilitation through qualitative analysis of user testing with PwS.

Acknowledgements: This project was funded by the Centre of Research Excellence in Medical Technologies, New Zealand.

6. REFERENCES

Cassidy, T (2011). The mood board process modeled and understood as a qualitative design research tool. *Fashion Practice*, **3**, *2*, pp. 225–251.

Buunk, AM, Groen, RJM, Wijbenga, RA, Ziengs, AL, Metzemaekers, JDM, van Dijk, JMC., and Spikman, JM (2018). Mental versus physical fatigue after subarachnoid hemorrhage: Differential associations with outcome. *European Journal of Neurology*, **25**, *11*, pp. 1313-e113.

Darbois, N, Guillaud, A, and Pinsault, N (2018). Do robotics and virtual reality add real progress to mirror therapy rehabilitation? A scoping review. *Rehabilitation Research and Practice*, **2018**, pp. 1–15.

Deconinck, FJA, Smorenburg, ARP, Benham, A, Ledebt, A, Feltham, MG, and Savelsbergh, GJP (2015). Reflections on Mirror Therapy: A Systematic Review of the Effect of Mirror Visual Feedback on the Brain. *Neurorehabilitation and Neural Repair*, **29**, *4*, pp. 349–361.

Endmann, A, & Keßner, D (2016). User journey mapping – a method in user experience design. *I-Com*, **15**, *1*, pp. 105–110.

Ferreira, B, Conte, T, & Barbosa, SDJ (2015). Eliciting requirements using personas and empathy map to enhance the user experience. *2015 29th Brazilian Symposium on Software Engineering*, pp. 80–89.

Gordon, NF, Gulanick, M, Costa, F, Fletcher, G, Franklin, BA, Roth, EJ, and Shephard, T (2004). Physical activity and exercise recommendations for PwS. *Stroke*, **35**, *5*, pp. 1230–1240.

Lang, CE, MacDonald, JR, Reisman, DS, Boyd, L, Jacobson Kimberley, T, Schindler-Ivens, SM, Hornby, TG, Ross, SA, and Scheets, PL (2009). Observation of amounts of movement practice provided during stroke rehabilitation. *Archives of Physical Medicine and Rehabilitation*, **90**, *10*, pp. 1692–1698.

Laver, KE, Lange, B, George, S, Deutsch, JE, Saposnik, G, and Crotty, M (2017). Virtual reality for stroke rehabilitation. *Cochrane Database of Systematic Reviews*, **11**, *11*, pp. 1-180

Lohse, K, Shirzad, N, Verster, A, Hodges, N, and Van der Loos, HFM (2013). Video games and rehabilitation: Using design principles to enhance engagement in physical therapy. *Journal of Neurologic Physical Therapy*, **37**, *4*, pp. 166-175.

Martin, B, and Hanington, B (2012). *Universal Methods of Design* (1st ed.). Rockport Publishers, London.

Miller, KK, Porter, RE, Debaugn-Sprague, E, Van Puymbroek, M, and Schmid, AA (2017). Exercise after stroke: Patient adherence and beliefs after discharge from rehabilitation. *Topics in Stroke Rehabilitation*, **24**, *2*, pp. 142–148.

Pyae, A, Yuen, TB, and Gossage, M (2013). Human-centered design: Persona development for interactive rehabilitative games for stroke patients. *ResearchGate*, pp. 154–159.

Reynolds, F (2012). Art therapy after stroke: Evidence and a need for further research. *The Arts in Psychotherapy*, **39**, *4*, pp. 239–244.

Rodríguez Ramírez, E (2017). A postgraduate thesis model for research through design based on design criteria. *The International Journal of Designed Objects*, **11**, *4*, pp. 11–27.

Stoykov, ME, and Madhavan, S (2015). Motor priming in neurorehabilitation. *Journal of Neurologic Physical Therapy*, **39**, *1*, pp. 33–42.

Thieme, H, Morkisch, N, Mehrholz, J, Pohl, M, Behrens, J, Borgetto, B, and Dohle, C. (2018). Mirror therapy for improving motor function after stroke. *Cochrane Database of Systematic Reviews*, **2012**, *3*, pp. 1-66.

Weber, LM, Nilsen, DM, Gillen, G, Yoon, J, and Stein, J (2019). Immersive virtual reality mirror therapy for upper limb recovery following stroke: A pilot study. *American Journal of Physical Medicine & Rehabilitation*. **98**, *9*, pp. 783-788.

Naturalistic Locomotion for Patients in VR-based Supermarket Tasks

Paul Chojecki[1], Detlef Runde[2], David Przewozny[3], Mustafa T. Lafci[4], Michael Gaebler[5], Johanne Tromp[6], Stephan Krohn[7], Felix Klotzsche[8], Mykyta Kovalenko[9], Julia Belger[10], Angelika Thöne-Otto[11], Carsten Finke[12], Oliver Schreer[13], Peter Eisert[14]

[1,2,3,4,9,13,14] Vision & Imaging Technologies, Fraunhofer Heinrich Hertz Institute HHI
Einsteinufer 37, 10587 Berlin, Germany

[5,6,8] Department of Neurology, Max-Planck Institute for Human Cognitive and Brain Sciences,
Leipzig, Germany

[7,12] Department of Neurology, Charité-Universitätsmedizin Berlin
Berlin, Germany

[10,11] Clinic for Cognitive Neurology, University Hospital Leipzig
Leipzig, Germany

[1]*paul.chojecki@hhi.fraunhofer.de*, [2]*detlef.runde@hhi.fraunhofer.de*, [3]*david.przewozny@hhi.fraunhofer.de*, [4]*mustafaTevfik.Lafci@hhi.fraunhofer.de*, [5]*gaebler@cbs.mpg.de*, [6]*tromp@cbs.mpg.de*, [7]*stephan.krohn@charite.de*, [8]*klotzsche@cbs.mpg.de*, [9]*mykyta.kovalenko@hhi.fraunhofer.de*, [10]*julia.belger@medizin.uni-leipzig.de*, [11]*angelika.thoene@medizin.uni-leipzig.de*, [12]*carsten.finke@charite.de*, [13]*oliver.schreer@hhi.fraunhofer.de*, [14]*peter.eisert@hhi.fraunhofer.de*

[1,2,3,4,9,13,14] *www.hhi.fraunhofer.de,* [5,6,8] *www.cbs.mpg.de,* [7,12]*neurologie.charite.de,* [10,11] *www.uniklinikum-leipzig.de/einrichtungen/tagesklinik-neurologie*

ABSTRACT

In this paper, we present two naturalistic Virtual Reality locomotion techniques for patients with cognitive disorders. For evaluation and training in virtual supermarkets, two shopping cart-metaphors with a physical handlebar for steering and additional stability support were implemented: (1) a simulation of a standard shopping cart, for standing users, (2) a simulation of a motorized shopping cart for seated users. To initiate locomotion they either simulate real walking, in one place or press a controller button. Preliminary results indicate that our system is well optimized for patients and against cybersickness. We also present general recommendations and optimal parameters for locomotion.

1. INTRODUCTION

The supermarket task is a widely used method to evaluate and train patients with cognitive disorders e.g., executive functions and spatial memory (e.g., Josman et al., 2008). Here, test subjects (accompanied by a therapist) have to plan and perform a shopping task in a (real-world) supermarket.

Immersive technologies such as Virtual Reality (VR) or Augmented Reality (AR) are currently experiencing rapid development. This opens up new possibilities for diagnostic and therapeutic applications. A VR implementation of the supermarket task can offer various advantages compared to a real-world supermarket, such as accessibility, full controllability of design, task difficulty etc., as well as automated data acquisition and analysis in a naturalistic virtual environment. A current overview about possibilities, challenges and solution approaches for multidimensional evaluations of VR paradigms in clinical neuropsychology is provided by Krohn et al., 2020.

One of the most important aspects of such a VR implementation is the ability to navigate and interact with the virtual world and its objects. This should be effortless, practicable with a simple technical setup, avoiding cybersickness effects and minimally violating rules of the physical world, in order to facilitate its use and maximize its diagnostic and therapeutic usefulness.

2. BACKGROUND

The objective of this paper is to present a new locomotion technique for VR systems used in diagnosis and therapy of cognitive impairments (e.g., in dementia, stroke). The work is part of the VReha R&D project (VReha, n.d.) concerning "Virtual worlds for digital diagnostics and cognitive rehabilitation". In contrast to conventional methods, e.g. paper-and-pencil tests or complex, yet less controllable real-world, immersive VR tasks can evaluate and train cognitive abilities relevant to everyday life in naturalistic but standardized environments. Such VR approaches are expected to be significantly more sensitive, precise and meaningful. This will potentially contribute to an earlier and more sensitive diagnosis of cognitive disorders, e.g., regarding early stages of dementia. Furthermore, VR-based personalized disorder profiles can be created to determine and implement VR-based outpatient therapy programs, eventually leading to an improved, ecologically relevant treatment of cognitive disorders. Within the VReha project, we developed – inter alia – an immersive virtual supermarket task (imVST) for the assessment of executive functions, which is described in more detail below.

2.1 Supermarket task

Various VR supermarket systems have been developed and reported in the literature (see Xi et al., 2019, for an overview). Even when described as 3D or VR, most of the reported supermarket systems are 2.5D applications, i.e., presentations of 3D environments on a 2D screen. Early systems are reported by Klinger et al., 2006, Renner et al., 2010, and Dyck et al., 2012, a current one is described by Lu et al., 2019.

The imVST discussed in this paper is an immersive VR application presented on a head-mounted display (HMD) and enables naturalistic 3D visualization and interaction. Users are asked to shop for several products in an efficient way and for that, they need to navigate and traverse the supermarket alleys in a natural way, while searching for products and collecting them in their cart. A broad range of parameters related to navigation performance (e.g., deviation from ideal path), memory performance (e.g., number of remembered shopping items) and executive function (e.g., efficiency of shopping strategies) can be collected here to assess cognitive function.

2.2 VR locomotion & navigation

One of the major challenges of the imVST and other VR (supermarket) task implementations is the navigation and locomotion in large-scale virtual worlds as well as the interaction with virtual objects. We use the terms locomotion and navigation as follows: *locomotion* is the ability to move from location *A* to location *B* in a virtual world. *Navigation* is a subtask of locomotion and covers the deliberate change of direction. Especially in diagnostic and rehabilitation VR tasks both should be effortless, as natural as possible, require minimal extra technology and be operable in a clinical laboratory or even in the patient's home. Central challenges to all implementations are usability and the elimination of symptoms of cybersickness experienced by the user (see sec. 2.3).

Numerous locomotion and navigation methods have been published. **Real walking** would be the most intuitive and natural solution, but for that the real physical space would have to be at least as large as the virtual world represented in a task. **Redirected walking** uses the effect that movements on a circular path at a sufficiently large radius are perceived as straight-ahead movements. It can be a solution for spatially limited virtual environments, but according to Grechkin et al., 2016 a large real space of at least 11.6 m in diameter is necessary to implement an unrestricted virtual space. **Treadmills** can be considered for clinical use with physically fit individuals, but they are less suitable for home use even for trained patients, because of the need for additional technical equipment, complex cabling and securing of the patient, as the walking surface is (intentionally) slippery. VR supermarkets typically use **controller-based locomotion** and interaction (Speicher et al., 2018). The controller-thumbstick based translational movement in VR induces cybersickness and is often replaced by **teleportation**, which reduces sensory conflicts since the user changes the location instantaneously (Langbehn 2018). Teleportation is especially suitable to switch between areas of interest or to cover large distances, but it is less suitable to explore the virtual world in detail, especially in search tasks, and it hampers spatial orientation (Bowman, 1997). **Flying**, as another way to reduce cybersickness, is a suitable metaphor for exploring landscapes like in Google Earth, but less suitable for indoor applications. Body movements imitating walking in one spot are used for the **walking in place** metaphor (WIP). This is a natural option to simulate or activate locomotion (Feasel et al., 2008) and suitable to locomote large VR spaces even if the real interaction area is small.

All of these solutions are not designed to meet the various clinical requirements and reduce cybersickness. Thus an easy to use, accessible "design for all" locomotion technique is still required. Based on the WIP idea we developed such a VR locomotion metaphor which, for example supports the postural instability of patients and allows users to stand or sit while traversing the imVST (see sec. 3).

2.3 Cybersickness

During imVST development we had to focus on reduction of cybersickness symptoms since they often are induced by locomotion and strongly influence user´s VR acceptance. Cybersickness represents a well-known adverse effect in all kinds of VR setups, inducing symptoms of discomfort, nausea and vertigo. The simulator sickness questionnaire (SSQ, Kennedy et al., 1993) is a well-established tool to assess the symptoms of cybersickness and its determinants. While its exact causes remain unknown, different theories exist: The postural instability theory explains cybersickness as a consequence of the body's failure to maintain postural stability while experiencing new stimuli (Riccio & Stoffregen, 1991). The sensory conflict theory explains cybersickness in terms of a sensory mismatch, i.e., our visual system experiences movement, while other senses like our vestibular system report inertia. There have been numerous studies to measure and reduce cybersickness-influencing factors (see e.g., Saredakis et al., 2020). For example, movement speed, user characteristics (e.g., gender, age), and content parameters have been investigated. One way to alleviate cybersickness is to manipulate the viewing setting such as the field of view and framing of the virtual world, e.g., with a virtual cockpit. Including a fixed reference object to the user's position, such as a virtual nose, helps to decrease cybersickness (Whittinghill et al. 2015). A different approach to reduce cybersickness is to switch to the 3rd person perspective of the virtual avatar as soon as the user is moving (Cmentowski et al., 2019).

2.4 Sensing & understanding body inputs

There are numerous sensor systems for the detection of body movements that are suitable to implement WIP based locomotion for VR. Typical sensors are 3D cameras (Guy et al., 2015), 3D tracking systems (Verhulst et al., 2016), pressure sensors (Shi et al, 2019) or the Inertial Measurement Unit (IMU) of the VR glasses (Hanson et al, 2019). Depending on the underlying technology, the systems differ in latency, granularity of control, robustness, simplicity of setup, software development availability and quality, as well as costs for hard- and software. These different sensing technologies have – to our knowledge – not been compared within the same VR application. Besides the direct comparison of different hardware systems, the quality of the software implementation is difficult to evaluate. Therefore, an a priori selection of the ultimate set-up for a specific VR task remains challenging.

3. SYSTEM DESIGN

Users of clinical VR applications should be able to focus only on the relevant task at hand, with minimal additional cognitive load from the VR environment, i.e. the behaviour in VR should be as intuitive as possible. Users should be able to navigate, locomote and manipulate objects easily in the virtual environment. The implementation should be suitable for diagnostics and for training, both in clinical use and at home. All patients should feel comfortable performing VR tasks of extended duration; in VReha VR sessions can last up to 50 minutes. Since some patients are not able to stand for this duration, a facultative seated condition should be provided. Nevertheless, physically fit users should not be forced to sit. Learning to use a VR controller adds cognitive load and holding the controller during the whole session adds physical strain, both should be avoided.

To meet the above mentioned requirements a VR locomotion concept with two variants, one for standing and one for sitting test subjects was designed, prototypically implemented and tested. Our approach is based on the idea of a standard shopping cart (sec. 3.1, standing condition) and a motorized shopping cart (sec. 3.2, seated condition). Both are implemented with the same hard- and software. Our **camera-based motion tracking** software allows **contact- and cable-free** detection and interpretation of user activities such as knee bending or WIP, leaning sideward and hand gesturing. The Kinect 2 sensor and its API provides us with the skeleton data to implement the use of body movements for navigation and movement in VR. A combination of filters and a rule-based system enables a smooth recognition of user movements even if tracking errors occur, as for example inaccurate foot positions, mixing legs, when crossing the feet and loosing knees when they are narrow. Our WIP implementation is enhanced with a **low-cost handlebar** mounted on a tripod. It provides a physical anchor and additional stability and immersion during the steering of the virtual cart for both variants. As in real life, the handlebar is used to change the direction of the cart (Fig. 1 and 2). A standard VR controller is mounted to the handlebar to detect and track its position and rotation using the VR system's built-in controller tracking. By that we map a virtual handlebar to the real handlebar for an accurate representation within the virtual environment and also provide a fixed reference between real and virtual world.

The locomotion system can be adjusted using several parameters to fit different conditions in order to reduce cybersickness: **maximum speed** (how fast the user can move in the virtual environment), **acceleration** (how fast the maximum speed is reached), and **deceleration** (how quickly the user stops when no movement command is detected) are the main variables to calculate the forward and backward movement. The **turning speed** is also adjustable to better fit the different shopping carts or input conditions (e.g., seated or standing). The number of parameters provides many possible combinations. Within the implementation, we prioritized the reduction of cybersickness and, if necessary, accepted minor limitations in functionality, such as slow movement. Additionally we adapted the content of the virtual environment. Our **guided curves** implementation includes a **dynamic field of view restriction**. Shelves in the curves were filled with non-task relevant content according to the search task (see 3.2). These objects could not be grabbed because you only regain control after you have already passed them. In a first approach, the settings for standing and seated users were the same, but as this was not optimal (e.g., guided movements when standing), we iteratively adjusted the parameters: field of view restriction, locomotion speed and acceleration / deceleration, haptic feedback, guided movement, as described in sec. 3.2.

The imVST is implemented in Unity and runs at a stable 90 frames per second with 5 real-time light sources while the camera-view is rendering up to a maximum of 400,000 polygons per frame on a PC with an NVIDIA GTX 1080 GPU and an Intel Xeon six-core CPU at 3.5GHz. To meet the hardware requirements for this use case we selected Oculus Rift HMD for this setup. A Leap Motion, mounted to the VR headset, is used for hand detection and natural interaction within the imVST Unity-App. Our extensions to standard Leap Motion tracking are described in detail in Chojecki et al. (2019).

3.1 Standing condition

3.1.1 Pre-Trials

To find the best solution for our imVST we evaluated different approaches for forward/backward and rotational movements (Guy et al., 2015) without and with assistive devices, in pre-trials. The forward/backward movement was controlled either by moving one foot (forward or backward) or slightly bending one or both knees. The rotation was controlled by shoulder or upper body rotation, hip movement or rotation, or oblique movement of one foot to the right or the left. With extensive expert evaluations and specific focus on patient users, we determined that:

- oblique foot movements are less suitable for turning, as users quickly lose balance
- simultaneously moving and rotating leads to slightly more cybersickness as compared to separate straight walking and rotation
- in the supermarket scenario, shoulder rotation to perform a rotational movement is problematic because users want to look around and orientate themselves at the same time
- in general, rotational body movements require practice
- knee-bending was preferred for straight movements since users tend to lose balance with foot movements
- a handlebar is useful to keep balance and give confidence to the user

From these pre-trials, the following design decisions are derived: **rotational movements should not be controlled by body movements** and forward movement should be implemented by knee-bending. These results of our evaluation stand in contrast with the results presented by Guy et al., 2015. For verification of these authors' findings, we tested our locomotion method in front of a 2D display. In this configuration, cybersickness and balance issues are not severe. It indicates that findings from a 2.5D system cannot be transferred to VR glasses. For a 2.5D version of our system, the locomotion types have therefore to be tested again. A **real (physical) handlebar (stationary, but rotatable)** (Fig. 1), which corresponds to the handlebar of the shopping cart in VR, offers the advantage of naturalistic, intuitive navigation and provides a **balance aid**. This confirms the results in Carlson et al., 2011, who also combined a real shopping cart with a VR environment. The combination of our much easier to use Walk-In-Place implementation, that accepts real steps and simple knee bending for locomotion, and an additional handlebar for navigation convinced in the pre-trials and was iteratively enhanced for the imVST.

3.1.2 Implemented locomotion & navigation

While standing, the users hold the handlebar (Fig. 1) and walk in place or bend their knee(s) to move around. Here, a user-specific adaptation of speed and acceleration is available to minimize cybersickness. It is easy and useful to increase these settings step by step starting from low default values in order to find optimal values for each user. The users stop upon releasing the handlebar with at least one hand. They can then "stop & shop": go to the shelf, grab a product, go back to the cart and put the product inside. This procedure combines WIP to move forward and real walking within the secure guardian area. Having users move their body to initiate locomotion in the virtual world should help to decrease sensory conflicts and therefore reduce the risk of cybersickness.

Figure 1. *Shopping cart (standing condition)*

3.2 Seated condition

In this condition users are seated in a virtual electric wheelchair with a front mounted basket for shopping (Fig. 2 a). The handlebar of this motorized cart has a corresponding counterpart in the real world to hold on to, same as in the standing version (Fig. 2 b). It is additionally equipped with a controller of the VR-system, mounted with a special adapter (created with a 3D printer according to our requirements), which enables the user to **accelerate** and **decelerate** the wheelchair via button press, mimicking a throttle on the handlebar. The direction of travel is determined by turning the handlebar. To avoid shunting within the aisles, the width of the aisles was reduced from 1.5 m to approximately 1 m, compared to the standing condition. This design helps users to select products on both sides of the aisles without having to bend too far out of the seat, thus **avoiding the risk of falling** from the chair.

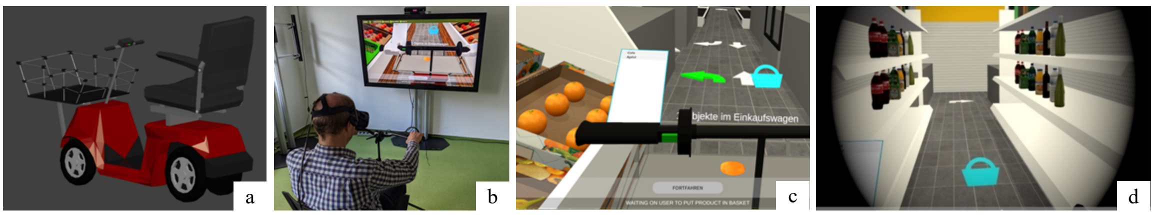


Figure 2. *(a) Virtual motorized shopping cart, (b) handlebar as corresponding counterpart (c)automatic guidance, indicated by arrows on the floor and (d) reduced field of view when turning around corners*

Several functionalities and parameters are implemented to minimize cybersickness when using the motorized cart. The display of the handlebar, which is firmly anchored to the user's position, and the shopping basket or even the shopping list should counteract any possible discomfort. A slight vibration of the handlebar provides **tactile feedback** while riding to simulate motorized movement and increase immersion. This is realized using the vibration facility of the controller, which is mechanically transferred to the handlebar. To reduce the sensory conflict between visual and vestibular system, **only slight accelerations and decelerations** are possible. To avoid long braking distances (which could cause the driver to miss the desired shelf when stopping for a product), the **maximum speed is limited** as well.

Preliminary tests showed that with the relatively narrow aisles, some users had difficulties to turn into another aisle without bumping into a shelf. In addition, cornering was found to increase cybersickness. Therefore, we implemented an option of **automatic guidance** for making a turn. Arrows are painted on the ground and the driver chooses a direction by steering towards the desired arrow. Feedback is given by colouring the chosen direction arrow (see Fig. 2 c). Shortly before arriving at the corner, the car movement is automatically controlled, and shortly after the turn, it is given back to the user. Therefore, car movement is a combination of user-controlled (active) and machine-controlled (passive) navigation. In the literature, the effect on automatic guidance on cybersickness has yielded mixed results (Chen et al. 2012 vs Venkatakrishnan et al. 2020).

As another method to reduce cybersickness when turning around corners, the **field-of-view was restricted** (Fernandes et al. 2016). We implemented this selectable option using the Unity plugin VR Tunneling Pro[2]. Following Fernandes et al. 2016, who reported that rotation contributes the most to nausea according to most participants. The field of view restriction (see Fig. 2 d) is only activated **for automated cornering**. For all parameters, conservative default settings were chosen (suitable for most users), but all can be configured individually.

Our system extends Dyck et al., 2012, by using VR glasses, real grabbing and the handlebar of the shopping cart and the field of view manipulation to reduce cybersickness.

4. PRELIMINARY FINDINGS & CONCLUSION

Based on extensive testing during the iterative development approach with experts, clinical staff and first patients (with different age, gender and experience), we can draw the following conclusions. The physical handlebar was a helpful link between VR and the real world, subjectively improving presence and –in the standing condition – serving as a balance aid. Speed, acceleration and deceleration should be limited to rather low values. We chose for the sitting condition a max. acceleration of 0.53 m/s^2 and a max. velocity of 0.53 m/s. For the standing conditions, these values were 1.06 m/s^2 and 0.84 m/s, respectively.

The standing/walking condition led to less cybersickness than the seated/driving condition. Especially the "stop & shop" concepts seem to be advantageous. In our experience, testing larger samples of heterogeneous users and analysing averages unfortunately cannot predict the best parameters for any individual user. For example, average speed settings often appear be too high or too low for individual users, which might make VR usage uncomfortable or boring. By implementing two versions of the imVST (standing and seated) for which multiple parameters can be individually adjusted, we have developed a VR application that can be adapted to individual user needs – to support task completion (even with bodily constraints), minimize the risk of cybersickness, and thus maximize the clinical outcome.

In the current system, it is not possible to do a U-turn inside an aisle or walk backward. This restriction was introduced due to a combination of cybersickness-reducing parameters and constraints of the VR environment (there is no space for a U-turn with a suitable minimal radius to prevent cybersickness). It should be investigated if this restriction has an influence on the test results.

For future developments, we suggest to determine interindividual VR compatibility parameters in advance in order to adjust the optimal settings for each user. Ideally, this can be done by a cybersickness pre-test in the specific usage context or by classifying potential users on a VR compatibility scale based on user characteristics such as age, gender or experienced motion sickness in real life (Freiwald et al., 2020). These baseline values should be adjusted regularly with prolonged VR use and associated training or habituation.

Based on the work presented herein, the next step is to systematically evaluate the imVST in a clinical context with both healthy volunteers and patients.

Acknowledgements: The work reported here has been supported by the Federal Ministry of Education and Research (BMBF) of the Federal Republic of Germany (project VReha, grant no. 13GW0206).

5. REFERENCES

Bowman, D.A., Koller, D., Hodges, L.F., 1997. Travel in immersive virtual environments: an evaluation of viewpoint motion control techniques, in: *Proceedings of IEEE 1997 Annual International Symposium on Virtual Reality. Presented at the Proceedings of IEEE 1997 Annual International Symposium on Virtual Reality, pp. 45–52*. https://doi.org/10.1109/VRAIS.1997.583043

Carlson, P., Kirpes, C., Pavlik, R.A., Vance, J.M., Yin, L., Scott-Cooper, T., Lambert, T., 2011. Comparison of Single-Wall Versus Multi-Wall Immersive Environments to Support a Virtual Shopping Experience, in: *ASME 2011 World Conference on Innovative Virtual Reality. Presented at the ASME 2011 World Conference on Innovative Virtual Reality*, ASMEDC, Milan, Italy, pp. 287–291. https://doi.org/10.1115/WINVR2011-5582

Chen, Y.-C., Dong, X., Chen, F.-C., Stoffregen, T.A., 2012. Control of a Virtual Avatar Influences Postural Activity and Motion Sickness. *Ecological Psychology 24*, 279–299. https://doi.org/10.1080/10407413.2012.726181

Chojecki P, Kovalenko M, Runde D, Przewozny D, Schreer O. Intentional, accurate and natural object placement in virtual reality based neuropsychological assessment. In: *2019 International Conference on Virtual Rehabilitation (ICVR).* ; 2019:1-3. doi:10.1109/ICVR46560.2019.8994457

Cmentowski, S., Krekhov, A., Krüger, J., 2019. Outstanding: A Multi-Perspective Travel Approach for Virtual Reality Games, in: *Proceedings of the Annual Symposium on Computer-Human Interaction in Play, CHI PLAY '19*. Association for Computing Machinery, Barcelona, Spain, pp. 287–299. https://doi.org/10.1145/3311350.3347183

Dyck, E., Zell, E., Kohsik, A., Grewe, P., n.d. OCTAVIS: An Easy-to-Use VR-System for Clinical Studies, The Eurographics Association 2012.

Feasel, J., Whitton, M.C., Wendt, J.D., 2008. LLCM-WIP: Low-Latency, Continuous-Motion Walking-in-Place, in: *2008 IEEE Symposium on 3D User Interfaces. Presented at the IEEE Symposium on 3D User Interfaces 2008, IEEE, Reno*, NE, pp. 97–104. https://doi.org/10.1109/3DUI.2008.4476598

Fernandes, A.S., Feiner, S.K., 2016. Combating VR sickness through subtle dynamic field-of-view modification, in: *2016 IEEE Symposium on 3D User Interfaces (3DUI). Presented at the 2016 IEEE Symposium on 3D User Interfaces (3DUI),* pp. 201–210. https://doi.org/10.1109/3DUI.2016.7460053

Freiwald, J. P., Göbel, Y., Mostajeran, F., & Steinicke, F. (2020). *The cybersickness susceptibility questionnaire: Predicting virtual reality tolerance.* In Proceedings of the Conference on Mensch und Computer (S. 115–118). Association for Computing Machinery. https://doi.org/10.1145/3404983.3410022

Guy, E., Punpongsanon, P., Iwai, D., Sato, K., Boubekeur, T., 2015. LazyNav: 3D ground navigation with non-critical body parts, in: *2015 IEEE Symposium on 3D User Interfaces (3DUI). Presented at the 2015 IEEE Symposium on 3D User Interfaces (3DUI)*, IEEE, Arles, France, pp. 43–50. https://doi.org/10.1109/3DUI.2015.7131725

Hanson, S., Paris, R.A., Adams, H.A., Bodenheimer, B., 2019. Improving Walking in Place Methods with Individualization and Deep Networks, in: *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR). Presented at the 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 367–376. https://doi.org/10.1109/VR.2019.8797751

Josman, N., Hof, E., Klinger, E., Marie, R.M., Goldenberg, K., Weiss, P.L., Kizony, R., 2006. Performance within a virtual supermarket and its relationship to executive functions in post-stroke patients, in: *2006 International Workshop on Virtual Rehabilitation. Presented at the 2006 International Workshop on Virtual Rehabilitation, IEEE*, New York, NY, USA, pp. 106–109. https://doi.org/10.1109/IWVR.2006.1707536

Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G., 1993. Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology 3*, 203–220. https://doi.org/10.1207/s15327108ijap0303_3

Klinger, E., Chemin, I., Lebreton, S., Marié, RM. Virtual action planning in Parkinson's disease: a control study. In: *Cyberpsychology & Behavior 2006 Jun;9(3)*, pp. 342-347

Krohn, S., Tromp, J., Quinque. E.M., Belger, J., Klotzsche, F., Rekers, S., Chojecki, P., de Mooij, J., Akbal, M., McCall, C., Villringer, A., Gaebler, M., Finke, C., Thöne-Otto, A. Multidimensional Evaluation of Virtual Reality Paradigms in Clinical Neuropsychology: Application of the VR-Check Framework. *J Med Internet Res 2020;22(4):e16724,* doi: 10.2196/16724 PMID: 32338614, PMCID: 7215516.

Langbehn, E., Lubos, P., Steinicke, F., 2018. Evaluation of Locomotion Techniques for Room-Scale VR: Joystick, Teleportation, and Redirected Walking, in: *Proceedings of the Virtual Reality International Conference - Laval Virtual, VRIC '18*. Association for Computing Machinery, Laval, France, pp. 1–9. https://doi.org/10.1145/3234253.3234291

Lu, C., Tanaka, J., 2019. A Virtual Shopping System Based on Room-scale Virtual Reality. *ACHI 2019: The Twelfth International Conference on Advances in Computer-Human Interactions,* ISBN: 978-1-61208-686-6

Lu, C., Liu, B., Tanaka, J., 2019. Implementing Hand Gestures for a Room-scale Virtual Reality Shopping System, *International Journal on Advances in Software,* vol 12 no 3 & 4, year 2019, http://www.iariajournals.org/software/

Renner, P., Dankert, T., Schneider, D., Mattar, N., Pfeiffer, T., 2010. Navigating and selecting in the virtual supermarket: review and update of classic interaction techniques, in: *Virtuelle Und Erweiterte Realitaet*: 7. Workshop Der GI-Fachgruppe VR/AR.

Riccio, G.E., Stoffregen, T.A., 1991. An ecological Theory of Motion Sickness and Postural Instability. *Ecological Psychology 3*, 195–240. https://doi.org/10.1207/s15326969eco0303_2

Saredakis, D., Szpak, A., Birckhead, B., Keage, H.A.D., Rizzo, A., Loetscher, T., 2020. Factors Associated With Virtual Reality Sickness in Head-Mounted Displays: A Systematic Review and Meta-Analysis. *Front. Hum. Neurosci. 14.* https://doi.org/10.3389/fnhum.2020.00096

Shi, X., Pan, J., Hu, Z., Lin, J., Guo, S., Liao, M., Pan, Y., Liu, L., 2019. Accurate and Fast Classification of Foot Gestures for Virtual Locomotion, in: *2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. Presented at the 2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), IEEE, Beijing, China, pp. 178–189. https://doi.org/10.1109/ISMAR.2019.000-6

Speicher, M., Hell, P., Daiber, F., Simeone, A., Krüger, A., 2018. A virtual reality shopping experience using the apartment metaphor, in: *Proceedings of the 2018 International Conference on Advanced Visual Interfaces*, AVI '18. Association for Computing Machinery, Castiglione della Pescaia, Grosseto, Italy, pp. 1–9. https://doi.org/10.1145/3206505.3206518

Venkatakrishnan, Roshan, Venkatakrishnan, Rohith, Bhargava, A., Lucaites, K., Solini, H., Volonte, M., Robb, A., Babu, S.V., Lin, W.-C., Lin, Y.-X., 2020. Comparative Evaluation of the Effects of Motion Control on Cybersickness in Immersive Virtual Environments, in: *2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR). Presented at the 2020 IEEE Conference on Virtual Reality and 3D User Interfaces* (VR), pp. 672–681. https://doi.org/10.1109/VR46266.2020.1581256520838

Verhulst, E., Richard, P., Richard, E., Allain, P., Nolin, P., 2016. 3D Interaction Techniques for Virtual Shopping: Design and Preliminary Study:, in: *Proceedings of the 11th Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications. Presented at the International Conference on Computer Graphics Theory and Applications, SCITEPRESS - Science and Technology Publications*, Rome, Italy, pp. 269–277. https://doi.org/10.5220/0005725402690277

VReha. (n.d.). Retrieved 29 January 2021, from https://www.vreha-project.com/en-gb/home

Whittinghill, D., Ziegler, B., Case, T., and Moore, B. Nasum virtualis: A simple technique for reducing simulator sickness. http://gtp.autm.net/technology/view/70738, 2015.Xi, N., Hamari, J., n.d. VR Shopping: A Review of Literature, Twenty-fifth Americas Conference on Information Systems, Cancun, 2019

Cognitive stimulation using VR on activities of daily living in people with mild to moderate dementia due to Alzheimer's disease

Jorge OLIVEIRA[a,b], Pedro GAMITO[a,b], Teresa SOUTO[a,b], Rita CONDE[a,b], Maria FERREIRA[a,b], Tatiana COROTNEAN[b], Adriano FERNANDES[c], Henrique SILVA[c] and Teresa NETO[c]

[a]*HEI-Lab / Lusófona University*
[b]*EPCV / Lusófona University*
[c]*Santa Casa da Misericórdia da Amadora*

Abstract. This research aimed to explore the effect of cognitive stimulation using virtual reality on people with mild to moderate dementia from Alzheimer's disease. Patients were recruited at the residential care homes from Santa Casa da Misericórdia da Amadora in Portugal. This intervention lasted 2 months and was composed of a total of 10 sessions (two sessions/week), with pre-post treatment assessments using established neuropsychological instruments. The sample consisted of 17 older adults with Alzheimer's disease that were randomly distributed by the experimental group with virtual reality and the control group consisting in continuous care without virtual reality. The results showed an improvement in global cognitive function in the experimental group, but no effects were found in specific cognitive domains, probably due to the small sample size. Preliminary results suggest some potential benefits of virtual reality cognitive stimulation for older adults with Alzheimer's disease, but further studies are needed with larger samples to explore in full the results of this approach in Alzheimer's disease.

Keywords. Alzheimer's Disease, Cognitive Stimulation, Virtual Reality, Activities of Daily Living.

1. Introduction

Alzheimer's disease (AD) is a neurodegenerative disease and the most common cause of dementia compromising cognitive function and the ability to carry out daily life activities [1]. Encouraging results have paved the way for further work in this field by proposing that ecologically oriented approaches consisting in virtual reality (VR) tasks that mimic instrumental daily activities may promote transfer of trained skills [2], while allowing to replicate conditions close to real life situations [3]. Therefore, this investigation aims to contribute to this topic by studying the effect of a VR cognitive stimulation program depicting activities of daily living in older adults with AD.

2. Methods

2.1. Sample

17 older adults (12 women) diagnosed with AD with a mean age of 83 years (M = 83.24: SD = 5.66), most with primary education.

2.2. Measures

1) Frontal Assessment Battery - FAB; 2) Trail Making Test - TMT; 3) Mini-Mental State Examination - MMSE; 4) Clock Drawing Test – CDT; 5) Lawton –Brody Instrumental Activities of Daily Living Scale - IADL; 6) Geriatric Depression Scale-15 – GDS-15; and 7) Clinical Dementia Scale - CDR.

2.3. Procedure

This study was approved by an ethics committee and informed consent was obtained from both participants and their caregivers (formal and informal). The participants were assessed for eligibility according to the following criteria: being older adults with AD, fluent in Portuguese language, above 65 years old keen to participate in the study. The sample was randomly divided by the experimental group (n = 10) and the control group (n = 7) before starting intervention conducted using the Systemic Lisbon Battery [2].

3. Results

The results suggested an improvement following intervention in the MMSE ($F(1, 15) = 4.930$; $Eta^2 = 0.247$; $p = .042$). The effect size on global cognitive function was considered large. No other statistically significant results were obtained ($p > .05$).

4. Conclusion

The results suggest generalized effects of VR cognitive stimulation using activities of daily living in older adults with AD, but further studies are needed to explore in full the results of this approach. The program was also well accepted by participants and the technicians that provided intervention, suggesting a promising role of VR in future behavioral interventions for AD.

References

[1] Lesuis, S. L., Hoeijmakers, L., Korosi, A., de Rooij, S. R., Swaab, D. F., Kessels, H. W, Krugers, H. J. (2018). Vulnerability and resilience to Alzheimer's disease: early life conditions modulate neuropathology and determine cognitive reserve. Alzheimers Res Ther. 10, 1-20.

[2] Oliveira, J., Gamito, P., Souto, T., Conde, R., Ferreira, M., Corotnean, T., Fernandes, A., Silva, H., Neto, T. (2021). Virtual Reality-Based Cognitive Stimulation on People with Mild to Moderate Dementia due to Alzheimer's Disease: A Pilot Randomized Controlled Trial. Int. J. Environ. Res. Public Health. 18(10).

[3] Parsons, T. D. (2015). Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences. Front. Hum. Neurosci. 9, 660.

Research in Serious Games for People with Intellectual Disability: a Meta-analysis Study

C Sousa, J C Neves, M J Damásio

CICANT, Lusófona University,
Lisbon, PORTUGAL

carla.patricia.sousa@ulusofona.pt, josecsn@ulusofona.pt, mjdamasio@ulusofona.pt

https://cicant.ulusofona.pt/

ABSTRACT

Currently, the potential of games as an intervention tool in a broad range of areas has been increasingly explored by researchers. Notwithstanding, and when considering individuals with Intellectual Disability (ID), the need for more data emerges, as well as the need to systematize and summarize such data, allowing evidence-based decisions to all the stakeholders in this field. The present study aimed to systematize the existing evidence regarding the effectiveness of serious games in the promotion of life skills in people with ID. Several scientific databases were consulted, as well as researchers' social networks to obtain a sample as wide as possible. Through a process composed by different phases, several inclusion and exclusion criteria were applied to the initial search results. The obtained sample of studies (N = 8) was then systematically analyzed, including a meta-analysis procedure, to summarize the quantitative data on the effectiveness of serious game based interventions for people with ID. Results from the meta-analysis study emphasize larger effect-sizes than conventional methods (non game-based) interventions with people with ID (fixed-effects, g = 0.417; 95% CI [0.169, 0.666]; Z = 3.293, SE = 0.127, p = .001) , in the promotion of a broad range of variables associated with well-being, from cognitive abilities to psychotherapy related skills. Such results can frame the discussion regarding serious games as a relevant and feasible strategy to promote skills in people with ID, allowing evidence-based decisions in this field, aimed at supporting an increasing and enhanced inclusion of games in their daily lives.

Keywords: Intellectual Disability; Serious Games; Systematic Literature Review; Meta-analysis.

1. INTRODUCTION

Intellectual Disability (ID) is defined as a disorder with onset during the developmental period that includes both intellectual and adaptive functioning deficits in conceptual, social and practical domains (APA, 2013). The social paradigms of approaching ID have been gradually changing, from social charity to social citizenship, through the inclusion - segregation - integration - inclusion path (Emygdio da Silva, 2009; Fontes, 2009). These changes are in line with the centrality currently attributed to the context in defining the effective disability of people with ID. According to the World Health Organization (WHO), although ID is seen as an health condition, from which results a set of impairments in body functions and structures, activity limitations, and participation restrictions, all these factors can only be understood when considering their complex interactions with the contextual factors, that comprise both personal factors and environmental barriers and hindrances (WHO, 2001). In the field of intervention, practices mainly based on medical/biological perspectives have been gradually replaced by more holistic perspectives (Emygdio da Silva and Coelho, 2009).

Currently, the potential of games as intervention strategies in the fields of learning (Sousa and Costa, 2018), cognition (Pallavicini et al., 2018; Rosa et al., 2016), and motivation (Granic et al., 2014) has been increasingly supported by research. Particularly, in the field of ID, games have been considered as a relevant alternative to the current therapy/training methods, though the recognized need for developing new and innovative games that can truly correspond to subjects' needs (Tomé et al., 2014). Moreover, games are also being discussed has having a potential to foster the decrease of the environmental barriers and hindrances that people with ID face in their specific contexts (Sousa, 2020).

Games for ID, as a specific field in game studies has been primarily focusing on three types of main aims: learning or skills promotion; the definition of methodologies for game design and game development; and the identification of patterns and behaviours in the use of video games by people with ID (Cano et al., 2015). The need for more empirical results and the methodological weaknesses of the existing studies in the field has also been highlighted (Cano et al., 2015; Jiménez et al., 2015).

In the broad field of social sciences, the increasing rate of studies being conducted, as well as the need to synthetize both the differences and similarities across studies, their methodologies and results, place the need to organize and summarize the existing research as a priority, compared with the need to develop completely new research. One of the possible methods to effectuate such progression in an area of knowledge is through the conduction of meta-analysis, a methodological and statistical approach to drawing conclusions from empirical literature (Card, 2012).

Besides research, also in the field practice, the selection of interventions and treatments must be considered the most critical activity of practitioners committed to improving the outcomes and lives of individuals with ID. Therefore, is crucially important for them to know the most effective interventions or evidence-based programs for such population. Moreover, evidence-based practices in the field of ID are considered as relevant for all the involved stakeholders, but more directly for teachers, administrators, service providers, and support teams. Aligned with this, the need to widespread the application of such practices for individuals with ID is currently considered a high priority for improving the outcomes with this population (Stoiber et al., 2016).

The present study aims to summarize the most recent evidence on the effectiveness of serious games in the promotion of a broad range of life skills in people with ID, through a meta-analysis study. Ultimately, it is expected that the obtained results allow evidence-based decisions in this field, aimed at supporting an increasing and enhanced inclusion of serious games in the intervention practices with this population.

2. METHOD

2.1 Sample Selection Process

Studies primarily focusing on people with intellectual disability were included in the sample. The use of a specific "gold standard" diagnosis for participants to be classified as ID was not considered as an inclusion criterion. Studies were included regardless of participants' type or degree of ID. Studies primarily focusing on people with dementia and Alzheimer's disease were excluded, as well as studies approaching other disabilities, like learning disabilities, such as Attention Deficit Hyperactivity Disorder (ADHD), that are frequently confused in literature.

Studies were included if there was a control group for comparison, and if they make usage of serious games as a strategy to promote any type of life skill, compared with conventional intervention methods. Regarding the research design, to be included studies must constitute experimental approaches and, most specifically, Randomized Controlled Trials (RCTs). A broad definition of serious games was adopted, considering the premise that "not all game characteristics, such as, challenge, fun and play are appropriate descriptions or labels for all serious games" (Marsh, 2011). Thus, studies making usage of games, simulations, or experimental/experiential environments with a purpose (Marsh, 2011) were included in the sample.

Since this meta-analysis is part of a broader Systematic Literature Review study, the schematic search process did not start by searching only for RCTs, with this inclusion criteria being applied in the end of the eligibility phase. The process started with a schematic scientific database search, including Ebsco, PubMed, B-On (the largest database in Portugal, with most of the other ones associated with it), Academia.edu, and ResearchGate, by using the following terms and Boolean operators: [games AND (intellectual disability)]. Variations of this search formula included different forms of designating ID, such as "cognitive disability", "intellectual disabilities", other expressions such as "serious games" among others. Academia.edu and ResearchGate were also used as a data collection tool, to access Grey Literature, explicitly eventual research outcomes not controlled by commercial publishers. This process constitutes the Identification phase of the SLR.

The following phases were based in a set of inclusion criteria set out above, regarding ID and serious games. To be included, studies must also be published in sources that include a peer-review process, and clearly approach the use of games for the promotion of life skills in people with ID. Additionally, and considering the study aim of systematizing the most recent scientific evidence, the included studies were published between January 2010 and February 2020 (the systematic search was developed in early March 2020).

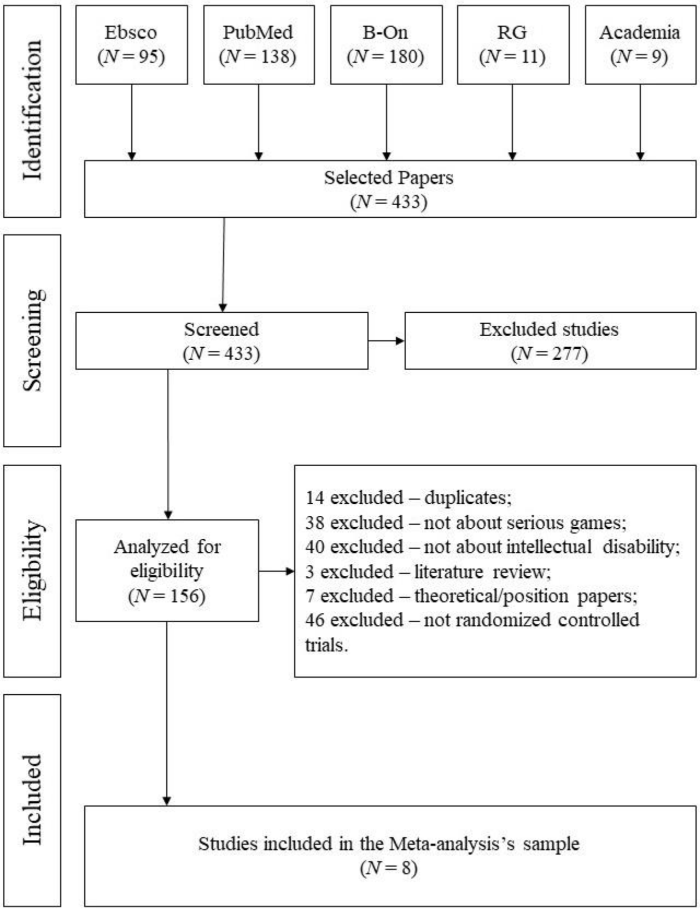


Figure 1. *Flowchart of the sample selection process.*

Using the above defined criteria, 8 scientific papers were included in the final sample. The selection process throughout this sample is represented in Figure 1. In the Screening phase, the criteria were applied at a superficial level, meaning that only titles, abstracts and general information were considered. In the Eligibility phase the criteria was followed by thoroughly analysing each study, before deciding on including or excluding it. The final sample is composed by: Study 1 (Choi et al., 2012); Study 2 (Söderqvist et al., 2012); Study 3 (Tsimaras et al., 2014); Study 4 (Brankaer et al., 2015); Study 5 (Siberski et al., 2015); Study 6 (García-Villamisar et al., 2017); Study 7 (Cooney et al., 2017); and Study 8 (Silva et al., 2017).

2.2 Data Analysis

The selected papers were analysed considering two different matrices. First, some general aspects of the research were categorized, namely year of publication, sample size (*N*), sample age group, aspects regarding ID, research aims, expected intervention's outcomes, and aspects regarding serious games and platform. The gathered data was then analysed using the Statistical Package for the Social Sciences (IBM SPSS), version 22. Next, studies were analysed considering the reported quantitative results, which were summarized using the Comprehensive Meta-Analysis Software (CMA), version 2.

In the meta-analysis, hedges'*g* was adopted since it provides a superior estimate of the standardized mean difference in small samples (Higgins et al., 2003). Considering the nature of the meta-analysis results and nonstatistical assumptions regarding studies similarity, a fixed-effects model was also adopted (Tufanaru et al., 2015).

3. RESULTS

3.1 Overview of Studies

Eight studies matched the inclusion criteria. The present meta-analysis as a total sample of 301 subjects with ID, with an average of 37.63 individuals per included study. Samples in the studies ranged between 20 and 62 subjects.

Regarding the year of publication, it is possible to observe that all studies are from the last 10 years. Therefore, it can be safeguarded that the reported data corresponds to the most recent scientific evidence. The distribution by years was as follows: 2012 – two studies (25.0%), 2014 – one study (12.5%), 2015 – two studies (25.0%), 2017 – three studies (37.5%).

Five studies in this meta-analysis (62.5%) had a sample composed by adults, while three studies (37.5%) were mainly focused on children and/or youth. The samples were mainly composed by individuals with ID. In some cases, researchers indicated further specifications about the diagnosis, particularly concerning the level of impairment (e.g. mild ID) or the existence of comorbidities (e.g. ASD, anxiety, or depression). It is relevant to note that all the studies (N = 5; 62.5%) specifying further conditions regarding ID and the level of impairment had included individuals with mild or mild to moderate ID in the sample (Brankaer et al., 2015; Choi et al., 2012; Cooney et al., 2017; Silva et al., 2017; Tsimaras et al., 2014). Further information on sample composition and characterization of the studies in this sample is detailed on Table 1.

Table 1. *Characterization and composition of the studies in the sample (N = 8).*

Study ID	**Sample Size**	**Sample characterization**
Study 1	N = 29	"Students under the age of 18, with mild intellectual disability and attending primary one to three were recruited." (Choi et al., 2012)
Study 2	N = 41	"All participants had ID (IQ < 70, retrieved from clinical records) and were registered with the mental habilitation center in the area of Buskerud in Norway." (Söderqvist et al., 2012)
Study 3	N = 20	"This study involved 20 adults aged 20-25 years (…), and with moderate ID (IQ: 35-50) (…)" (Tsimaras et al., 2014)
Study 4	N = 30	"Participants were 30 children with mild ID (…)" (Brankaer et al., 2015)
Study 5	N = 32	Adults with ID (Siberski et al., 2015).
Study 6	N = 40	"(…) adults with ASD and ID who met DSM-IV criteria (…)" (García-Villamisar et al., 2017)
Study 7	N = 52	"Fifty-two adults with mild to moderate ID and anxiety or depression (…)" (Cooney et al., 2017)
Study 8	N = 27	"Twenty-seven adults with Down Syndrome (DS) (…)" (Silva et al., 2017)

Considering the main aim of the studies in this sample we can broadly state that they intended to explore the promotion of life skills in people with ID through interventions based on serious games. We can consider as life skills, a broad range of variables, that can be directly or indirectly associated with well-being, from cognitive abilities to psychotherapy-related skills. Most specifically, the studies aimed to the promotion of: skills associated with the so-called Daily Life Activities (Choi et al., 2012); cognitive abilities (García-Villamisar et al., 2017; Siberski et al., 2015; Söderqvist et al., 2012); behavioural aspects, associated with other clinical symptomatology (Cooney et al., 2017; Tsimaras et al., 2014); learning associated outcomes (Brankaer et al., 2015); and physical/motor outcomes (Silva et al., 2017). It is relevant to clarify the expected outcomes above categorized are not mutually exclusive, and it is possible to hypothesize that improvements on cognitive abilities can ease individuals' performance on daily life activities or learning tasks, for example. Nevertheless, since the studies did not present data regarding skills transferability, these categories were developed based on the aims systematized on Table 2.

Table 2. *Main aims of the studies in the sample (N = 8).*

Study ID	*Aim*
Study 1	*"To motivate children ID to learn handwashing and improve their performance by using computer-assisted teaching method." (Choi et al., 2012)*
Study 2	*"(…) we investigated the feasibility of cognitive training for improving Working Memory (WM) and Non-Verbal Reasoning (NVR)." (Söderqvist et al., 2012)*
Study 3	*"The purpose of this study was to examine the effect of a digital interactive game in distractibility, hyperactivity, impulsiveness and other relative symptoms in individuals with Attention Deficit Hyperactivity-Disorder (ADHD) and ID." (Tsimaras et al., 2014)*
Study 4	*"(…) we developed and evaluated a numerical domino game that specifically targeted the association between these digits and the numerical magnitudes they represent." (Brankaer et al., 2015)*
Study 5	*"To investigate whether participants with ID would improve in cognitive function after cognitive training (…)" (Siberski et al., 2015)*
Study 6	*"(…) to examine effects of a therapeutic recreation program designed to increase Executive Function (EF), social skills, adaptive behaviours and well-being of adults with Autism Spectrum Disorder (ASD) and ID." (García-Villamisar et al., 2017)*
Study 7	*"To evaluate the utility of a Cognitive-Behavioural Therapy (CBT) computer game for adults who have an intellectual disability." (Cooney et al., 2017)*
Study 8	*"This study aims to analyse the effects of a Wii-based exercise program on physical fitness, functional mobility and motor proficiency of adults with DS." (Silva et al., 2017)*

Several games were used in the studies, from the ones specifically aimed at cognitive training aimed to commercial games, which can be justified by the broad concept of serious games adopted in this meta-analysis. Choi et al (2012) used a simulation game based, where the interaction was based on a tangible hand washing station (with faucet, soap dispenser, and towel). Both Siberski et al. (2015) and Söderqvist et al. (2012) used serious games based on already existing cognitive training applications and/or computerizes tasks for the intervention. Tsimaras et al. (2014) intervention was based on a digital interactive tennis game, and Silva et al. (2017) also adopted sports-related motion-based games, in this case commercial ones. García-Villamisar et al. (2017) included "instructional electronically based games" in their therapeutic recreation intervention strategy. Cooney et al. (2017) adapted a previously developed CBT game and mobile application for children to the needs of adults with ID, suffering from anxiety and/or depression. Brankaer et al. (2015) is the only study in the sample using an analogical serious game, in this case a numerical domino game. Regarding the games' platforms, most were computer games (N = 5; 62.5%); followed by motion-based games, for Nintendo Wii or another non-specified platform (N = 2; 25.0%); and one analogical game (12.5%).

3.2 Meta-analysis

In Study 1, results showed that children with ID can improve their handwashing skills, using a tangible simulation game (Choi et al., 2012) (g = 0.087: CI = 95%; -0.657 – 0.832). Study 2 supported children's improvements in WM and NVR through their inclusion in an intensive and computerized adaptive cognitive training process (Söderqvist et al., 2012) (g = 0.017; CI = 95%; -0.585 – 0.619). In study 3, a digital interactive game was effective to improve distractibility, hyperactivity and impulsivity in adults with both ID and ADHD (Tsimaras et al., 2014) (g = 2.333; CI = 95%; 1.225 – 3.441). Study 4 makes usage of an analogical numerical domino game to effectively increase children's learning outcomes regarding numbers and the numerical magnitudes they represent (Brankaer et al., 2015) (g = 0.358; CI = 95%; 1.225 – 3.441). In Study 5, adaptive computerized cognitive training was used to effectively improve cognitive training in adults with ID (Siberski et al., 2015) (g = 0.248; CI = 95%; -0.577 – 1.074). Study 6 reports EF gains in adults with ID, through their enrolment in leisure activities that include electronically based games (García-Villamisar et al., 2017) (g = 0.736; CI = 95%; 0.108 – 1.365). In Study 7, a CBT computer game was used to to produce clinically significant change in anxiety symptoms in adults with ID (Cooney et al., 2017) (g = 0.506; CI = 95%; -0.065 – 1.078). Study 8 supports Wii based exercises as an effective tool to improve physical fitness, functional mobility and motor proficiency in adults with ID, most specifically DS (Silva et al., 2017) (*g* = 0.088; CI = 95%; -0.671 - 0.847).

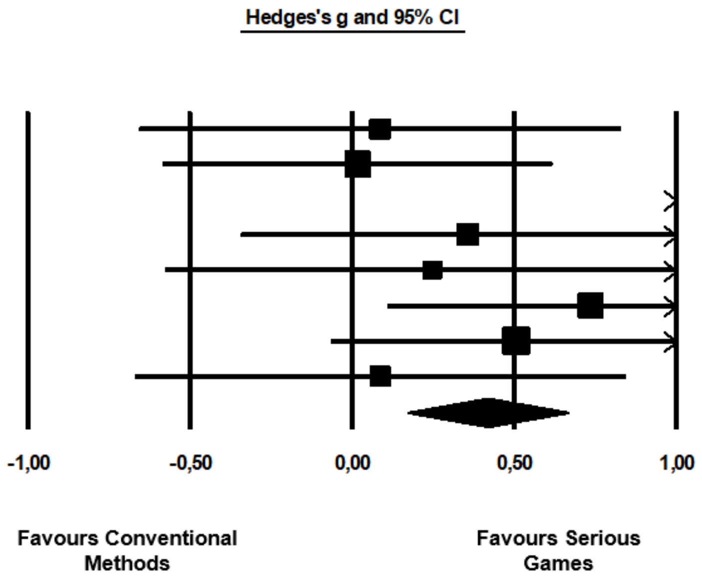


Figure 2. *Forest plot for effect sizes (Hedge's g) and 95% confidence intervals from individual studies.*

Using a fixed-effect analysis, the effect ratio for the eight studies was 0.417 with a confidence interval of 0.169 to 0.666, which indicates that interventions based on serious games can increase the interventions' outcomes by at least 15%, and perchance by as much as 65% in comparison with conventional methods (Z = 3.293, SE = 0.127, p <.005). Results are shown in Figure 2.

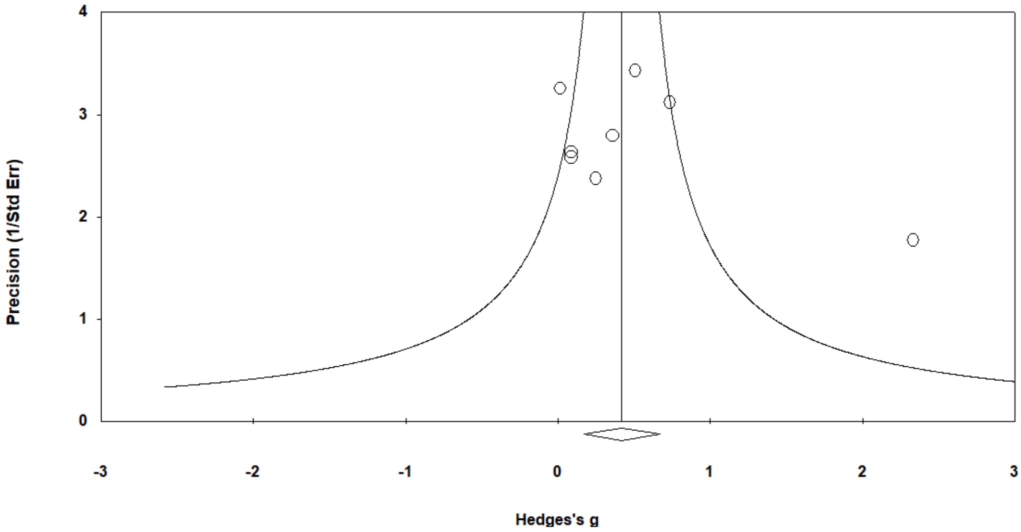


Figure 3. *Funnel plot of precision (Hedge's g)*.

The studies have demonstrated an absence of reporting bias since the funnel plot was symmetrical, as shown in Figure 3. The heterogeneity between studies in the analysis is significant and moderate (I2 = 56.069; p < .05).

4. CONCLUSIONS

The present study analysed a sample of eight studies, from an initial search including more than 400 studies, aiming to summarize the most recent evidence on the effectiveness of serious games in the promotion of a broad range of life skills in people with ID. In the sample's summarized results, the approaches based on serious games seems to show consistent gains in the promotion of several different skills in individuals with ID. The meta-analysis results point towards the existence of statistically significant differences between groups, being the interventions including serious games more effective than other conventional intervention methods.

Considering these data, using serious games can be considered a valid approach in the process of promoting skills in individuals with ID, supported by enough scientific evidence to frame its wider adoption as an intervention methodology. The obtained data regarding the effect-sizes of such interventions allow evidence-based decisions in this field, aimed at supporting an increasing and enhanced inclusion of games in the daily lives of people with ID. In addition, the collected sample shows that significant differences are found with both children and adults, and in the promotion of different types of skills, including the ones related with daily life activities, cognitive abilities, psychotherapy outcomes, motor outcomes, or learning-related abilities. This data strengthens the transversal potential of serious games in biopsychosocial approaches with individuals with ID, considering their ability to promote several skills within one type of intervention. This data also reinforces the prominent future of serious games as valuable intervention tools, with populations where the therapeutic answers are often seen as limited.

Some limitations of this study may include some heterogeneity of the research designs and the requirement for RCT as a factor of exclusion of a significant part of the sample studies, ending with a sample size not as larger as initially hypothesized. Also, RCTs frequently assess pre and post skills in the samples' individuals, without assessing their progress in the intervention, including motivational aspects, or other more subjective constructs, that can also be very relevant.

Future research must include the studies that are being carried out, separating the analysis of effectiveness by more specific aspects, for example regarding the serious games, age groups, or the context where the study was developed. Moreover, aspects related with specific game designs, gameplay environments, and game mechanics should be analysed, regarding its effectiveness in the intervention, and discriminating the most suitable for the promotion of each group of skills. Considering the lack of experimental approaches with RCTs in this field, that conditioned the sample size of this study, future studies should also consider the need to adopt research designs as systematic as possible and to report the obtained data in detail. Other relevant aspect regarding serious games and ID that would be relevant in futures studies is the exploration of the transferability of the obtained outcomes to subjects' daily lives, and to activities outside the scope of the study.

Acknowledgements: The present work was developed in the scope of ID Games (www.idgames.eu) international project, funded by the European Commission (2019-1-EL01-KA204-062517), under the Erasmus+ programme, framed in the cooperation actions for innovation and exchange in good practices – strategic partnerships for adult population (Key Action 2).

5. REFERENCES

American Psychiatric Association, (2013), *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)*. American Psychiatric Association, Arlington, VA.

Brankaer, C, Ghesquière, P, and Smedt, BD, (2015), The Effect of a Numerical Domino Game on Numerical Magnitude Processing in Children with Mild Intellectual Disabilities, *Mind, Brain, and Education*, 9, *1*, pp. 29-39.

Cano, AR, García-Tejedor, A, and Fernández-Manjón, B, (2015), A Literature Review of Serious Games for Intellectual Disabilities. In *Design for Teaching and Learning in a Networked World - Lecture Notes in Computer Science* (G Conole, T Klobučar, C Rensing, J Konert, and E Lavoué, Eds), Springer, New York, pp. 560 - 563.

Card, NA, (2012), *Applied Meta-Analysis for Social Science Research*, The Guilford Press, New York.

Choi, KS, Wong, PK, and Chung, WY, (2012), Using computer-assisted method to teach children with intellectual disabilities handwashing skills, *Disabil Rehabil Assist Technol*, 7, *6*, pp. 507-516.

Cooney, P, Jackman, C, Coyle, D, O'Reilly, G (2017), Computerised Cognitive-Behavioural Therapy for Adults with Intellectual Disability: Randomised Controlled Trial, *Br J Psychiatry*, 211, *2*, pp. 95-102.

Emygdio da Silva, MO, (2009), Da Exclusão à Inclusão: Concepções e Práticas, *Rev Lus Educ*, 13, pp. 135-153.

Emygdio da Silva, MO, and Coelho, F, (2009), Da deficiência mental à dificuldade intelectual e desenvolvimental, *Rev Lus Educ*, 28, pp. 163-180.

Fontes, F, (2009), Pessoas com deficiência e políticas sociais em Portugal: Da caridade à cidadania social, *Revista Crítica de Ciências Sociais*, 86, pp. 73-93.

García-Villamisar, D, Dattilo, J, and Muela, C, (2016), Effects of therapeutic recreation on adults with ASD and ID: a preliminary randomized control trial, *J Intellect Disabil Res*, 61, *4*, pp. 325-340.

Granic, I, Lobel, A, and Engels, R, (2014), The benefits of playing videogames, *American Psychologist*, 69, pp. 66-78.

Higgins, JPT, Thompson, SG, Deeks, JJ, and Altman, DG, (2003), Measuring inconsistency in meta-analysis*, British Medical Journal*, 327, pp. 557-560.

Jiménez, MR, Pulina, F, and Lanfranchi, S, (2015), Video games and Intellectual Disabilities: a literature review, *Life Span and Disability*, 18, *2*, pp. 147-165.

Marsh, T, (2011), Serious games continuum: Between games for purpose and experiential environments for purpose, *Entertainment Computing*, 2, pp. 61-68.

Pallavicini, F, Ferrari, A, and Mantovani, F, (2018), Video Games for Well-Being: A Systematic Review on the Application of Computer Games for Cognitive and Emotional Training in the Adult Population, *Front Psychol*, 9.

Rosa, P, Sousa, C, Faustino, B, Feiteira, F, Oliveira, J, and Lopes, P et al. (2016). The effect of virtual reality-based serious games in cognitive interventions. *Proc REHAB '16*, Lisbon, pp. 113-116.

Siberski, J, Shatil, E, Siberski, C, Eckroth-Bucher, M, French, A, Horton, S, Loefflad, RF, and Rouse, P, (2015), Computer-Based Cognitive Training for Individuals with Intellectual and Developmental Disabilities: Pilot Study, *Am J Alzheimers Dis Other Demen*, 30, *1*, pp. 41-48.

Silva, V, Campos, C, Sá, A, Cavadas, M, Pinto, J, Simões, P, Machado, S, Murillo-Rodríguez, E, and Barbosa-Rocha, N, (2017), Wii-based exercise program to improve physical fitness, motor proficiency and functional mobility in adults with Down syndrome, *J Intellect Disabil Res*, 61, *8*, pp. 755-765.

Söderqvist, S, Nutley, SB, Ottersen, J, Grill, KM, and Klingber, T, (2012), Computerized training of non-verbal reasoning and working memory in children with intellectual disability, *Front Hum Neurosci*, 6, pp. 1-8.

Sousa, C, (2020), Empowerment and ownership in intellectual disability gaming: review and reflections towards an able gaming perspective (2010-2020), *International Journal of Film and Media Arts*.

Sousa, C, and Costa, C, (2018), Videogames as a learning tool: Is game-based learning more effective?, *Rev Lus Educ*, 40, pp. 199-210.

Stoiber, KC, Pardy, S, and Klingbeil, DA, (2016), Evidence-Based Practices, In *Handbook of Evidence- Based Practices in Intellectual and Developmental Disabilities* (N Singh, Ed), Springer, Cham, pp. 41-68.

Tomé, R, Pereira J, and Oliveira, M, (2014), Using Serious Games for Cognitive Disabilities, *Serious Games Development and Applications*, pp. 34-47.

Torres-Carrión,PV, González-González, CS, Toledo-Delgado, PA, Muñoz-Cruz, V, Gil-Iranzo, R, Reyes-Alonso, N, and Hernández-Morales, S, (2019), Improving Cognitive Visual-Motor Abilities in Individuals with Down Syndrome, *Sensors*, 19, pp. 1-20.

Tsimaras, V, Papaioannou, M, Proios, M, Fotiadou, E, Kokaridas, D, and Kotzamanidou, M, The effect of a digital interactive game in distractibility, hyperactivity and impulsivity in individuals with attention deficit hyperactivity disorder and intellectual disability, *J Phys Educ Sport*., 14, 4, pp. 500-506.

Tufanaru, C, Munn, Z, Stephenson, M, and Aromataris, E (2015), Fixed or random effects meta-analysis? Common methodological issues in systematic reviews of effectiveness, *Int J Evid Based Healthc*, 13, *3*, pp. 196-207.

World Health Organization, (2001), *International Classification of Functioning, Disability and Health*, WHO, Geneva.

Predicting motor behavior: an EEG signal processing pipeline to detect brain states with potential therapeutic relevance for VR-based neurorehabilitation

Eric J. McDermott[1,2,3*], Johanna Metsomaa[1,2], Paolo Belardinelli[1,2],
Moritz Grosse-Wentrup[4], Ulf Ziemann[1,2], Christoph Zrenner[1,2]

[1] *Department of Neurology & Stroke, Eberhard Karls University Tübingen, Germany*

[2] *Hertie Institute for Clinical Brain Research, Eberhard Karls University Tübingen, Germany*

[3] *International Max Planck Research School, and Graduate Training Center of Neuroscience, Tübingen, Germany*

[4] *Faculty of Computer Science, Research Platform Data Science and Vienna Cognitive Science Hub, University of Vienna; Austria*

* Corresponding author:

Eric McDermott

E-Mail: EricJamesMcDermott@gmail.com

ABSTRACT

Background: Ongoing brain dynamics predict behavior; in the case of movement intention this takes the form of the *Bereitschaftspotential* (Kornhuber et al. 1965), *Contingent Negative Variation* (Walter et al. 1964), and the *Lateralized Readiness Potential* (Eimer 1998), where a negative potential in the contralateral hemisphere corresponds to the decision of which hand will be selected in a left vs. right movement paradigm. General topographical and power-related findings have been well studied, and brain computer interface approaches utilizing machine learning classifiers are increasingly accurate at predicting upcoming movement choices from linear combinations of EEG channels at any given point of time. There is a clear potential to apply these advances to increase the effectiveness of personalized therapy of neurological dysfunction, but there is also a clear gap between what's possible in a scientific versus clinical context due to limitations such as time and uncertainty in methodological choices.

Objective: We present an EEG analysis pipeline optimized within the constraints of clinical applications that is able to detect a therapeutically relevant brain state in real-time. The goal was to find the simplest solution that yielded sufficient performance for each of the steps in the analysis pipeline: (1) spatial selection of EEG channels, (2) temporal selection of relevant time window, (3) feature extraction method, (4) classification method, (5) number of trials. We also investigated which parameters benefit from individual calibration and where the use of averaged optimal settings as default parameters is sufficient.

Methods: 11 right handed healthy volunteers were enrolled in this study following approval of the local ethics committee, and they each performed a single measurement session. The task consisted of 1080 free-selection trials where a virtual cube in front of the subject (go signal) was to be contacted with the left or right hand. No further instructions were given. 126 channel high-density EEG was recorded during the task with a sampling rate of 5kHz. The paradigm was built in Unity3D using C#, hand movements were tracked using the Leap Motion Hand Tracker. Pre-movement EEG data epochs were first reduced in dimensionality with PCA, and then features were extracted using ICA. In a calibration phase, we used a self-optimizing 5-fold cross validated linear model to then create a personalized classification model. This model, combined with an individual's ICA weights, is used to predict movement selection.

Results: We were able to reproduce previous results that successfully predicted upcoming hand use before stimulus onset with a significant vs. chance accuracy found in all subjects. We found a significant improvement of accuracy when using optimal spatial and temporal settings, up to beyond 95% accuracy in single subjects, indicating that it is not only the instantaneous brain state but also the trajectory in state space that is relevant. Importantly, our calibration pipeline was performed in under 20 minutes with modest computational equipment, suggesting the ability for practical use in clinical environments.

Conclusions: With the aforementioned pipeline, we have demonstrated successful prediction of motor selection through pre-movement EEG data analysis, and through our calibration methodology, we are closer to closing the gap between clinical and scientific possibility. Our paradigm design allowed us insight into the brain-state both prior to the presentation of a visual stimulus, and also to include the time after the visual stimulus but prior to movement initiation. This capability further extends the opportunities for therapeutic advantages within XR through the advancement in precision timing that is synchronized with ongoing brain state fluctuations.

In particular, we have two temporarily distinct moments of stimuli manipulation: (1) using a time window prior to movement onset (here, the type of the stimulus in the VR world can be controlled; i.e., the presentation of virtual movements), and (2) using a time window prior to visual stimulus onset (here, the type and position of the stimulus can be controlled by EEG; i.e., stimuli positioning). Practically speaking, we are able to administer rehabilitation tasks according to the "What, When, Whether Model of Intentional Action" (Brass et al. 2008); such that we are able to determine with some prediction accuracy what the motor intention is (I want to move my left arm), as well as when they want to move this arm (synchronized with the patients' volition), and whether the movement will be executed (according to the reaching of a certain threshold). Each of these factors has its own set of specific use-cases: Knowing what the motor intention is allows us to present virtual avatars for example of an arm reaching toward a stimulus to those who have paretic limbs, this is akin to mirror therapy (Altschuler et al. 1999); only in our case utilizing a top-down endogenous brain-state-driven method instead of a bottom-up visually-driven method. Knowing when a patient would like to move an impaired arm allows us to present therapeutic targets for the impaired limb at exactly the time when they might be most successful, leading to a beneficial reinforcement loop. And knowing whether a patient will execute a movement altogether allows us to create more adaptive and tailored therapy, where stimuli presentation follow the patients' attention and motivation levels. Taken together, these findings are foundational blocks in the design of the larger rehabilitation system.

REFERENCES

Altschuler EL, Wisdom SB, Stone L, Foster C, Galasko D, Llewellyn DME, Ramachandran VS (1999) Rehabilitation of hemiparesis after stroke with a mirror The Lancet 353:2035-2036

Brass M, Haggard P (2008) The what, when, whether model of intentional action The Neuroscientist 14:319-325

Eimer M (1998) The lateralized readiness potential as an on-line measure of central response activation processes Behavior Research Methods, Instruments, & Computers 30:146-156

Kornhuber HH, Deecke L (1965) Hirnpotentialänderungen bei Willkürbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente Potentiale Pflüger's Archiv für die gesamte Physiologie des Menschen und der Tiere 284:1-17

Walter WG, Cooper R, Aldridge V, McCallum W, Winter A (1964) Contingent negative variation: an electric sign of sensori-motor association and expectancy in the human brain nature 203:380-384

Size and behaviour of virtual objects may be important for cognitive and motor rehabilitation: preliminary results

I Cikajlo[1, 2], K Grabljevec[1], T Klun[1], P. Rogelj[1], G Češarek Vučko[1], D Zajc[1], A Hukić[1], K Perme Sušnik[1], M. Vidmar[1], A Udovčić Pertot[1]

[1]University Rehabilitation Institute
Lihartova 51, Ljubljana, SLOVENIA

[2]University of Nova Gorica
School of Engineering and Management
Vipavska 13, Nova Gorica, SLOVENIA

[1]*imre.cikajlo@ir-rs.si*

[1]*www.uri-soca.si*

ABSTRACT

Motor control and learning of small range movements of upper extremities is rather important in rehabilitation of people with multiple sclerosis. We may expect functional and behavioural improvement in pick and place tasks due to brain plasticity resulting increased quality of life. For that purpose we have developed a virtual environment for pick and place of virtual cubes with variable sizes and behaviour. The person's hand and fingers movement were detected by a small table-top 3D infrared camera and reflected in virtual environment. The objective of the study was to examine the impact of size and behaviour of virtual cubes on motor control, motivation and performance in pick and place task.

In the preliminary study 22 patients with multiple sclerosis participated. The participants were equally randomized in two groups; one exercising with small bouncing cubes and the second with large but non-bouncing virtual cubes. Within three weeks the participants carried out 10 sessions each lasting 30 min/day and took psychological tests and Box & blocks functional test before and after the sessions. We found significantly slower movements with small and bouncing virtual object, but more focused, precise and challenging. The preliminary results may show guidelines for designing therapeutic tasks for precise small objects manipulation.

1. INTRODUCTION

Multiple sclerosis (MS) is a disease that affects the central nervous system and reduces functionality in daily tasks; problems with vision, balance, coordination, functional movements, concentration, etc. It can lead to permanent disability, but its cause is not completely known. The neuromotor rehabilitation of patients with MS require several types of exercises and virtual reality (VR) and exergaming have been suggested as a potential tools (Massetti et al., 2016). Several studies successfully applied non-immersive equipment, rarely reported on advantages of fully immersive equipment (Cikajlo and Peterlin Potisk, 2019) and no evidence has been provided that VR approach has been superior to conventional approaches. However, there are some evidences that VR and exergaming is effective in improving motor function in upper extremities (Webster et al., 2021).

Grasping and fine finger movements may present an important task for persons with MS and using virtual objects in exergaming can increase the ability to target the desired task, change the object characteristics according to the required level or patients' visual, motor or cognitive capabilities.

The objective of the preliminary randomized pilot study was to examine the effects of different virtual objects manipulation on exergame performance, motivation and clinical outcomes at assumption that participants have had similar visual and cognitive capabilities.

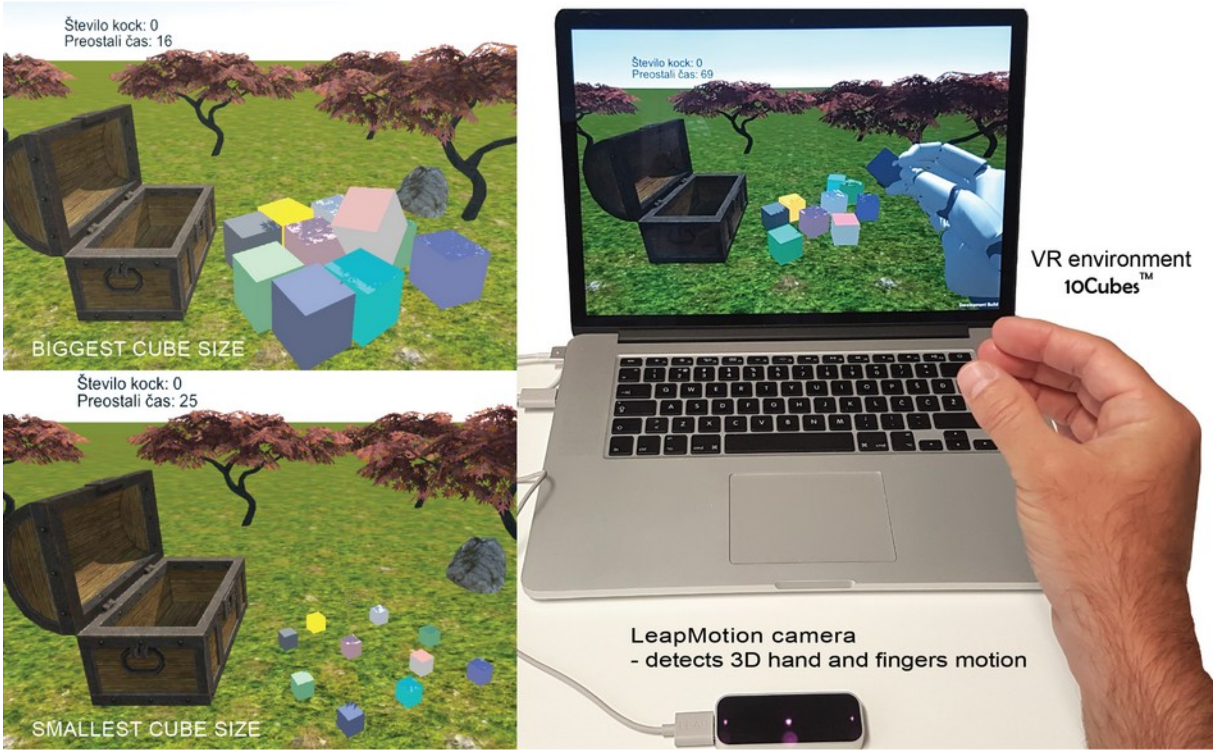


Figure 1. *Exergaming with 4 different tasks BIG or SMALL & (NON)-BOUNCING objects set objectives for motivation and fine neuromotor control of movement.*

2. METHODOLOGY

2.1 Equipment

The entire system was based on 3D kinematics assessed by the 3D infrared camera system Leap Motion Controller (LMC, Ultraleap Inc. Mountain View, CA, USA). The camera could accurately (Guna et al., 2014) detect hand and finger movements and transfer the data to the powerful laptop computer or mini-computer via USB with 100Hz. In conjunction with the 3D hand model developed in Unity3D (Unity Technologies, CA, USA) the kinematics of the hand and fingers was presented in the virtual environment and a scenery for exergaming had been developed (Cikajlo and Peterlin Potisk, 2019). For the purpose of the study variable sizes of virtual objects and materials were implemented. The user could choose from 2 different game sets: small virtual cubes with bouncing material and big cubes with (non) bouncing material (Fig. 1).

The exergame was displayed on the same computer screen for the duration of the study.

2.2 Subjects

In the ongoing randomized pilot study 22 patients (8 male, 14 female, age 50.5±12.8 years) of the local hospital with diagnosed multiple sclerosis participated. 59 patients were eligible for the study according to the inclusion criteria and were recruited. 15 participants did not finished the study due to the covid-19 outbreak. 22 participants were randomized into 2 different groups that are not subject of the presented study. Inclusion criteria: Mini mental state examination > 24, no visual disorders (use of own glasses), preserved function of upper extremity.

The recruited participants were randomized into 2 groups by computer random generator to get equal number of participants per group. The groups followed the same assessment protocol, but with different types of virtual cubes:

- group G1: small and bouncing cubes
- group G4: big and non-bouncing cubes

The study was approved by local ethics committee and all participants voluntarily provided a written consent. Participants could withdraw anytime without providing a reason.

2.3 Assessment protocol

The participants were seated in front of the table with laptop computer. The camera was placed on a table and covered the optimal working space (Fig. 1). An additional support for the participant's arm was provided if needed. The participants were requested to pick the virtual cubes in the virtual environment and place them in the open treasure box (Fig. 1) by the dominant hand. The cubes physical model (size, weight, material, bouncing factor) was defined selectively for each group and was equal for all members of the group.

The task remained the same (Cikajlo and Peterlin Potisk, 2019); the participant picked and placed the cubes one by one into the open chest within 120 s. The cube disappeared, when properly dropped in the chest. If all 10 cubes are successfully relocated earlier, then the task would be considered accomplished. The exergame started with 10 cubes randomly spread over the virtual environment.

Each participant took 10 training sessions in approximately three weeks. Each session lasted less than 30 min. allowing the participants to accomplish the task approximately 5 times. Short 2 min. breaks were taken between the trials. All participants filled the Intrinsic Motivation Inventory (IMI) (McAuley et al., 1989) immediately after each session.

Clinical tests, functional Box & Blocks (BBT) (Mathiowetz et al., 1985) Test and visuospatial cognitive tests, Delis–Kaplan Executive Function System (D-KEFS) (Delis et al., 2001), Judgment of Line Orientation test (JLO), (Benton et al., 1978) , (Moore and Denckla, 1999) and Frontal Assessment Battery (FAB), (Dubois et al., 2000) were performed at inpatient hospital before the treatment.

2.4 Data analysis

If there were major differences in psychological manner between the groups, the hypothesis for FAB (Kueider et al., 2012) , DKEFS and JLO would be confirmed or dropped by the Kruskal-Wallis, the non-parametric test for the non-normally distributed data.

Clinical test BBT was used to demonstrate the effectiveness of the intervention. The median values assessed prior to and after the sessions and indicated the 25th and 75th percentiles with whiskers at 1.5 times the interquartile range were calculated. By Friedman test the statistical interaction between the groups and the time factor were examined and the effect sized were checked by the Cohen's U3 index.

IMI tests were averaged across all participant in the group for each daily sessions and presented. Additionally statistical differences between the baseline and after training were examined with Friedman non-parametric test for unbalanced data.

Kinematics analysis of the hand were carried out for each session (Cikajlo and Pogačnik, 2020) . The 4 major indicators were followed: average time of manipulation of the cube, total time, number of successfully placed cubes and number of trials.

3. RESULTS

The psychological tests (Fig 2.) demonstrated no significant statistical differences between the participating groups; FAB ($p = 0.57$), JLO ($p = 0.69$), D-KEFS Visual scanning ($p = 0.41$), number sequencing ($p = 0.63$), letter sequencing ($p = 0.09$), number letter switching ($p = 0.74$) and motor speed ($p = 0.96$).

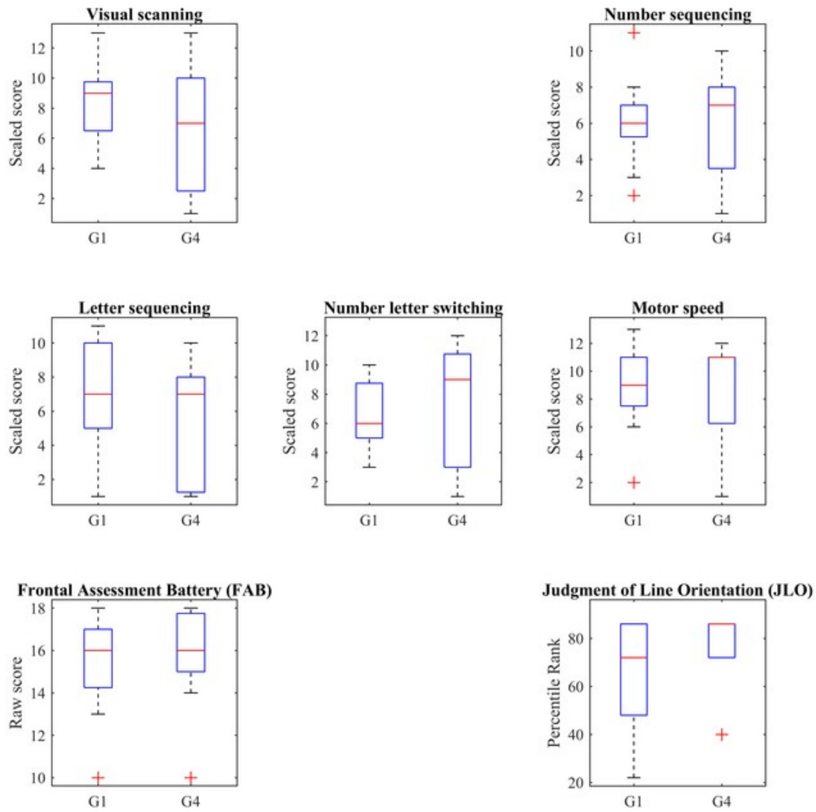


Figure 2. *Visual cognitive tests of Delis–Kaplan Executive Function System demonstrated differences between the groups in median value, but no significant statistical differences (p > 0.05) were found between groups neither with FAB or JLO.*

In average both groups performed equally with BBT after training. Group 4 had significantly higher median value (Fig. 3), but the Friedman test did not show significant statistical differences between the groups in time ($\chi2 = 1.607$, $p = 0.2049$). The effect sizes were small to medium for G1 (U3 = 0.6) and none for G4 (U3 = 0.5).

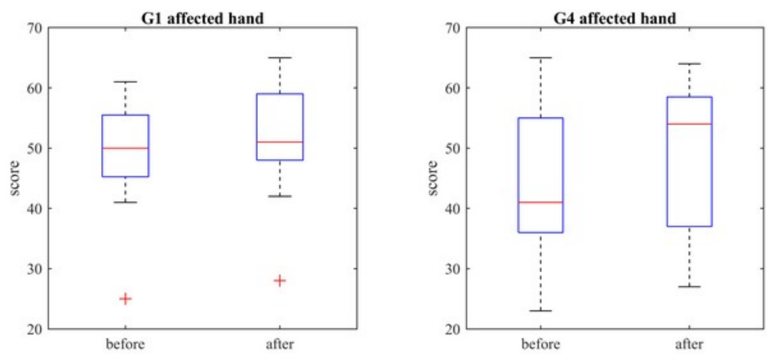


Figure 3. *Box and Block Test in general did not demonstrate statistical differences between the groups. However, both groups showed higher median score after the training.*

The Intrinsic Motivation Inventory (Fig. 4) showed an impact of the virtual cubes size and bouncing characteristics on the participants perception; group G1 constantly felt a bit of stress, but enjoyed the game and reported on perceived competences. On contrary the group G4 did not feel tension and their interest and enjoyment rate dropped after 5 sessions.

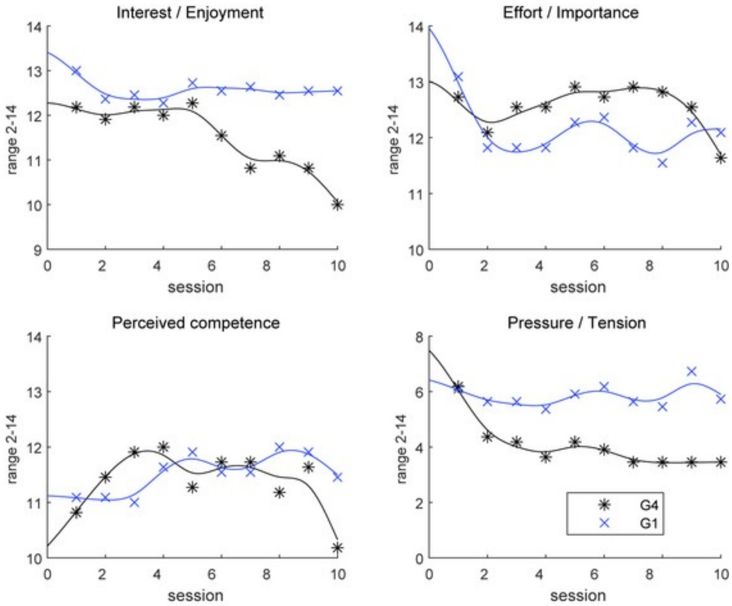


Figure 4. *The Intrinsic motivation inventory shows an impact of the virtual cubes size and bouncing characteristics on the participants perception; group G1 constantly felt a bit of stress, but enjoyed the game and reported of perceived competences. On contrary the group G4 did not feel tension and lost their interest and enjoyment after 5 sessions.*

Daily progress of kinematic and exergame measures (Fig. 5) was evident for the group G4. Total time (Time from the first touch to end) spent for the task was lower and the number of successfully placed virtual cubes was higher at rather unchanged number of total trials in 10 sessions.

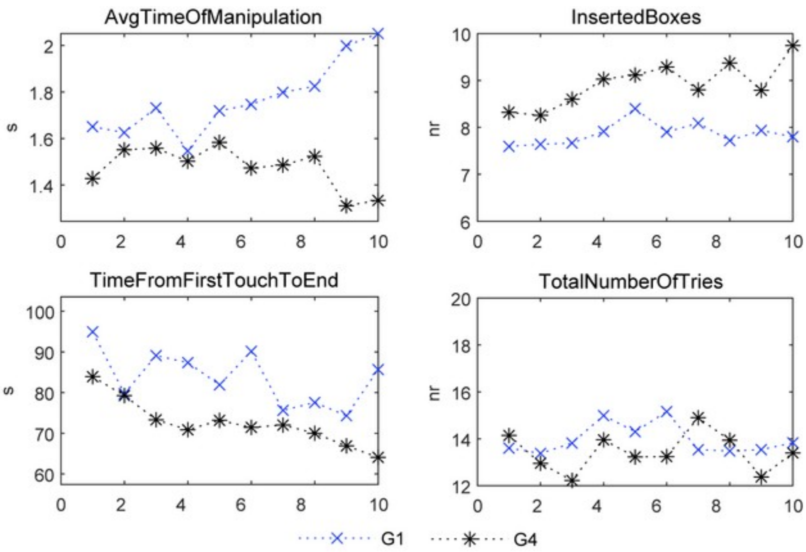


Figure 5. *The kinematic outcomes demonstrates that the participants of the group 4 have significantly decreased the average manipulation time and improve their efficiency (inserted boxes). Both groups were in general faster in performance after 10 sessions, but the average manipulation time of the cubes was much longer in group 1. This group was also less efficient.*

4. DISCUSION

The preliminary findings demonstrated significant impact of virtual objects' characteristics on motor control and exergame performance in the group of patients with MS with equal visual and cognitive capabilities. The limited clinical measures with BBT estimated only hand performance and showed progress which could not be confirmed statistically at this stage of the study.

As people with MS often suffer from vision problems and often have poor coordination, VR and exergaming may improve the small object manipulation function at least in short term. The variaty of virtual objects is important for the control of difficulty level, task objectives and as demonstrated in the study also fine motor control in upper extremities. At last and perhaps the most important outcomes of IMI are significant influence on the exergame performance. We found that the motivational factors like enjoyment, interest and stress may play an important role in expected clinical outcomes.

Acknowledgements: The authors would like to acknowledge the financial support to the Slovenian Research Agency (research core funding No P2-0228).

6. REFERENCES

Benton, A., Varney, N., and Hamsher, K. (1978). Visuospatial judgment. A clinical test. *Arch. Neurol.* 35, 364–367. doi:10.1001/ARCHNEUR.1978.00500300038006.

Cikajlo, I., and Peterlin Potisk, K. (2019). Advantages of using 3D virtual reality based training in persons with Parkinson's disease: a parallel study. *J. Neuroeng. Rehabil.* 16, 119. doi:10.1186/s12984-019-0601-1.

Cikajlo, I., and Pogačnik, M. (2020). Movement analysis of pick-and-place virtual reality exergaming in patients with Parkinson's disease. *Technol. Health Care* 28, 391–402. doi:10.3233/THC-191700.

Delis, D. C., Kaplan, E., and Kramer, J. H. (2001). *Delis-Kaplan Executive Function System: Examiner's manual*. San Antonio, TX: The Psychological Corporation.

Dubois, B., Slachevsky, A., Litvan, I., and Pillon, B. (2000). The FAB: a Frontal Assessment Battery at bedside. *Neurology* 55, 1621–1626. doi:10.1212/WNL.55.11.1621.

Guna, J., Jakus, G., Pogačnik, M., Tomažič, S., and Sodnik, J. (2014). An Analysis of the Precision and Reliability of the Leap Motion Sensor and Its Suitability for Static and Dynamic Tracking. *Sensors* 14, 3702–3720. doi:10.3390/s140203702.

Massetti, T., Trevizan, I., Arab, C., Favero, F., Ribeiro-Papa, D., and de Mello Monteiro, C. (2016). Virtual reality in multiple sclerosis - A systematic review. *Mult. Scler. Relat. Disord.* 8, 107–112. doi:10.1016/J.MSARD.2016.05.014.

Mathiowetz, V., Volland, G., Kashman, N., and Weber, K. (1985). Adult norms for the Box and Block test of manual dexterity. *Am. J. Occup. Ther.* 39, 386–391.

McAuley, E., Duncan, T., and Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: a confirmatory factor analysis. *Res. Q. Exerc. Sport* 60, 48–58.

Moore, B., and Denckla, M. (1999). "Neurofibromatosis," in *Pediatric Neuropsychology: Research, Theory, and Practice*, eds. K. O. Yeates and M. D. Ris (New York, New York, USA: Guilford Press), 149–170.

Webster, A., Poyade, M., Rooney, S., and Paul, L. (2021). Upper limb rehabilitation interventions using virtual reality for people with multiple sclerosis: A systematic review. *Mult. Scler. Relat. Disord.* 47. doi:10.1016/j.msard.2020.102610.

Synthetic agents: Relaxing agents?

P Gamito[1], T Souto[2], J Oliveira[3], R Conde[4], M J Ferreira[5], I Aleixo[6], E Teixeira[7], J A de Sousa[8], M Ferreira[9]

[1, 2, 3, 4,5,8] HEI-Lab: Human-Environment Interaction Lab, Lusófona University, Lisbon, PORTUGAL

[1,3] Faculty of Psychology and Life Sciences, Lusófona University, Lisbon, PORTUGAL

[2, 4, 5, 6, 7] Faculty of Psychology, Education and Sports, Lusófona University of Porto, Porto, PORTUGAL

[8,9] Faculty of Communication, Architecture, Arts and Information Technologies, Lusófona University of Porto, Porto, PORTUGAL

[1]*pedro.gamito@ulusofona.pt*, [2]*jorge.oliveira@ulusofona.pt*, [3]*p2638@ulusofona.pt*, [4]*p5025@ulusofona.pt,* [5]*p4652@ulp.pt,* [6]*p5033@ulp.pt,* [7]*p5902@ulp.pt,* [8]*p4086@ulp.pt,* [9]*p3859@ulp.pt*

[1, 2, 3, 4,5,8] *www.hei-lab.ulusofona.pt,* [1, 3] *www.ulusofona.pt,* [2,4,5,6,7,8,9] *www.ulp.pt*

1. FRAMEWORK

Virtual Reality (VR) has become a useful and effective resource in the field of psychology, namely in the treatment of anxiety, pain, and stress, and increasing well-being. Considering the efficacy of VR-based treatment for anxiety and related disorders, this resource has been considered as an alternative to an in vivo exposure for relaxation routines. Although VR effectiveness in treating anxiety disorders, pain, and stress has supported its increasing use in psychotherapy (Chandrasiri et al., 2020), the adoption of VR in relaxation training is not well documented.

While some authors report on the potential use of VR to promote relaxation and reduce stress and physiological activation, promising a relevant potential to improve and regulate emotional states (Pizzoli et al., 2019), there not many studies exploring the effectiveness of VR in reducing psychological. As relaxation is a cross-strategy for mental health problems, relaxation routines should be mandatory in any psychotherapeutic treatment plan (Tsitsi et al., 2017).

Relaxation can be defined as a decrease in the tension or the intensity of activation of the physical and mental dimensions (Andersen et al., 2017), which are mediated, at least in part, by a parasympathetic (or vagal) activation. This definition does not include reference to any physiological parameter value, nor does indicate how long does a patient takes to attain it. Relaxation seems to be an indicator of a positive lifestyle, mental health and, particularly of a positive outcome of the therapeutic approach (Charalambous et al., 2016). As such, virtual activities that can induce a state of relaxation must be included in existing and future VR therapeutic solutions.

The objectives were to develop a VR environment (VRE) for relaxation in order: (i) to estimate the time needed to reach such state in this environment, assessed by using physiological parameters as heart (HR) and respiratory (RR) rates along with relaxation perception through self-reports; and (ii) to assess the avatar´s impact when included in a VRE.

2. METHOD

Sixty nine young healthy Portuguese adults with a mean age of 28.14 years (SD = 12.29) were randomly allocated in one of 3 different conditions: 1) relaxation in VRE listening to relaxing instructions delivered by a synthetic agent (SyA; avatar) with a female voice; 2) relaxation in the same VRE while listening to the same instructions but aired by a radio set to the female voice from a radio; and 3) waiting to the end of the experience without relaxing instructions (control condition).

Participants were fitted with sensors to record HR and RR in order to obtain the 1st baseline evaluation (when seated, awake, in silence, but immersed in the virtual environment without other additional stimuli) following an activation task (matching game) for one minute. This task was followed by 12 minutes (relaxation period) guided relaxation task for participants in condition 1 and 2.

The guided relaxation exercise includes diaphragmatic breathing (slowing down respiration cycles, shifting to longer exhalations compared to inhalations, changing the respiration locus from the thorax to the abdomen) as well as guided imagery and visualization.

At the end of the exposure, all participants completed the Self-Assessment Manikin (SAM), the open-ended questions about the VR and the perception of relaxation, along with the self-report questionnaires for presence, immersion and cybersickness.

Regarding the materials and the equipment used, the experimental task was developed for VR using a laptop PC connected to an Oculus Rift S headset. This experimental task was developed by students from videogames degree in University Lusófona de Humanidades e Tecnologias (ULHT) from Lisbon (Portugal) that also developed the SyA model in iClone (Reallusion). The voice used in the relaxation routine was recorded from a senior psychologist in an ambisonics format, being imported to iClone for face animation and lipsync. Psychophysiology recording was done with a Biopac MP36 (Biopac Systems) using the respiratory belt transducer and the 3-lead ECG from Biopac in the Acq Knowledge Data Acquisition and Analysis Software (Biopac).

3. RESULTS

After 1 minute of relaxation, it was observed a decrease ($p < .05$) in HR and RR. The major variations occurred during the second minute of the relaxation routine (that corresponded to the VR breathing suggestions) with a decrease in HR and RR (all p's < .05). No differences to the baseline were found beyond the third minute of the relaxation task. The use of the SyA had no significant impact upon the guided relaxing exercise.

Regarding the qualitative data, 90% reported feeling relaxed, occurring mostly at the initial stage of the task. The participants emphasize, as main contributions for the relaxation, the voice/instructions and the breathing suggestions, which concur with the physiological data. The general VE and the voice were positively highlighted. Details of the environment (e.g., objects' disposition) and the control devices were less positively evaluated. 58% suggested some changes in details of the environment (e.g., size and arrangement of objects), luminosity and sound quality.

Overall, these data suggest that the relaxation task was effective for decreasing activation from the activation period within the initial phase of the virtual relaxation task. No significant differences were found between conditions for presence, immersion and cybersickness.

4. DISCUSSION AND CONCLUSION

The sense of control of the task – guided relaxation exercise – as measured by RR and by the verbal feedback from the participants, showed that the instructions induced relaxation. 2 minutes after the relaxing instruction (aired by SyA or radio set) start, 90% of the participants felt relaxed. The significant decrease observed in RR after 1 minute of relaxation suggest a cardiorespiratory parasympathetic control induced by the relaxation instruction (both SyA and radio conditions, but not in the control condition where no relaxing instruction was given). The sense of presence and of immersion were apparently a cornerstone for this VRE. The realism factor was possibly responsible for the participants to score on presence questionnaire significantly higher than an average participant.

The qualitative results reinforce the sense of presence in the VE, given that 90% of the participants report feeling the relaxation experience right in the initial phase of exposure (perception corroborated by the physiological data) and are highlighted by the VRE features reported as relevant factors for relaxation. All these aspects are related to realism factors mentioned above - namely aspects associated with the SyA (voice and instructions provided by the SyA) and the VRE in general.

The present work provides information on the peripheral physiological responses that best describe relaxation when conducted in a VRE, establishes an estimate duration and avatar's non-invasive role in a guided relaxation exercise. Based on this information, VRE may become an additional resource to the therapist's work when intervening in anxiety disorders and/or when homework is assigned to patient as well as a source of wellbeing.

5. REFERENCES

Anderson, AP, Mayer, MD, Fellows, AM, Cowan, DR, Hegel, MT, and Buckey, JC, (2017), Relaxation with immersive natural scenes presented using virtual reality, *Aerospace medicine and human performance*, **88**, *6*, pp. 520–526.

Carl, E, Stein, AT, Levihn-Coon, A, Pogue, JR, Rothbaum, BO, Emmelkamp, PM, Asmundson, GJ, Carlbring, P, and Powers, MB, (2018), Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials, *Journal of anxiety disorders*, *61*, pp. 27–36.

Chandrasiri, A, Collet, J, Fassbender, E, and De Foe, A, (2020), A virtual reality approach to mindfulness skills training, *Virtual Reality*, **24**, *1*, pp. 143–149.

Charalambous, A, Giannakopoulou, M, Bozas, E, Marcou, Y, Kitsios, P, and Paikousis, L, (2016), Guided imagery and progressive muscle relaxation as a cluster of symptoms management intervention in patients receiving chemotherapy: a randomized control trial, *PloS One*, **11**, *6*.

Kazzi, C, Blackmore, C, Shirbani, F, Tan, I, Butlin, M, Avolio, AP, and Barin, E, (2018), Effects of instructed meditation augmented by computer-rendered artificial virtual environment on heart rate variability, *40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Honolulu, pp. 2768–2771.

Pizzoli, SFM, Mazzocco, K, Triberti, S, Monzani, D, Alcañiz Raya, ML, and Pravettoni, G, (2019), User-centered virtual reality for promoting relaxation: an innovative approach, *Frontiers in Psychology*, *10*.

Tsitsi, T, Charalambous, A, Papastavrou, E, and Raftopoulos, V, (2017), Effectiveness of a relaxation intervention (progressive muscle relaxation and guided imagery techniques) to reduce anxiety and improve mood of parents of hospitalized children with malignancies: A randomized controlled trial in Republic of Cyprus and Greece, *European Journal of Oncology Nursing*, *26*, pp. 9–18.

Putting into a female body: the feasibility of the 360-degree video based virtual reality to induce the body swap illusion

Sara Ventura[1], Marta Miragall[2], Rosa Baños[3]

[1]Department of Psychology, University of Bologna,
40127 Berti Pichat Street, Bologna, ITALY

[2,3]Department of Personality, Evaluation and Psychological Treatments, University of Valencia,
46010 Blasco Ibañez Street, Valencia, SPAIN

[3]Polibienestar Research Institute, University of Valencia,
46022 Serpis Street, Valencia, SPAIN

[3]CIBERObn Physiopathology of Obesity and Nutrition, Instituto de Salud Carlos III,
Madrid, SPAIN

[1]*sara.ventura7@unibo.it*, [2]*marta.miragall@uv.es*, [3]*rosa.banos@uv.es*

ABSTRACT

The sense of embodiment refers to the ensemble of sensations of having, being located, and controlling a body mostly generate with various immersive technologies. The aim of this study is to investigate the feasibility of the 360-degree video to induce the sex-body swap from male real body to female virtual body, and to explore the correlation with the sense of presence, the cyber-sickness, and the psychological variables related to machismo trait.

1. INTRODUCTION

In the past decade, several studies have demonstrated the potentiality of Virtual Reality (VR) to induce the sense of embodiment (SoE), referred to a multisensory brain processes that give the illusion to have, move and be in the virtual body (Ehrsson, 2007). The body swap illusion could be induced using different VR systems, such as an ensemble of cameras connected to the Head Mounted Display (HMD), the optitrack suit that permits to display the body of the users into the virtual scenario, the machine to be another connected to the HMD (Matamala-Gomez et al., 2021). An alternative system able to induce the body swap illusion is the 360-degree camera, an affordable technology that record the surrounding environment (Repetto et al., 2018).

In previous studies, the SoE experienced by the participants during the study has been mostly based on the analysis of "external" factors such as the VR systems adopted or the avatar embodied, but the users' differences remain poorly researched (Dewez et al., 2019). However, during the embodiment induction some participants easily experience the illusion, and they drag themselves into the experience, while others are resistant to this experience (Dewez et al., 2019). Following these observations, the present work investigates how the sense of presence, and the individual psychological dimensions could influence the SoE, specifically in a gender body swap. The present study aims to investigate the feasibility of the 360-degree immersive video to generate the SoE in terms of location, ownership and agency; and to explore the associations between the SoE and the sense of presence, the cybersickness and the psychological variables associated to machismo trait.

2. METHOD

2.1. Participants

The study is addressed to male population. The exclusion criteria were: (1) being a man younger than 18 y/o, (2) having physical problems that could inhibit free movements; (3) history of SH with legal consequences; (3) use or abuse of drugs; and (4) receiving psychological treatments.

2.2. *Measures*

Sociodemographic Questionnaire; Interpersonal Reactivity Index (IRI) - internal consistency ranged from α = .60 to α = .87 -; Toronto Alexithymia Scale - internal consistency ranged from α = .51 to α = .91 -; Machismo and Caballerismo Scale - internal consistency: machismo (α = .80) and chivalry (α = .78) -; Embodiment, Presence, and Sickness - internal consistency: α = .88, α = .46, α = .87 -.

2.3. *Implementations and apparatus*

The 360-degree video was recorded with the LG360-105 camera, and it was edited with the Adobe Premiere Program. The video was recorded by a woman sit on a chair while doing some slow movements with their limbs. To generate the first-person perspective, the camera was fixed on the woman head. During the experiment, the video was played with the HMD through the VRPlayer software, and the participants were invited to synchronized as much as possible their movements with the performer to generate the body illusion (Fig 1).

Figure 1. The 360-degree video: *(a) = recording the video; (b) = participant's perspective; (c) = man participant doing the experiment.*

3. RESULTS

Participants: 44 males (M_{age}= 26.20, SD_{age}= 8.36). Embodiment scale: one-sample *t*-test indicated that embodiment scores were significantly greater than the chance level of 4 for location (M = 5.82, SD = 1.33), t(43) = 9.04, $p <$ .001, and ownership (M = 5.12, SD = 1.10), t(43) = 6.79, $p <$.001; but not for agency (M = 4.28, SD = 1.50), t(43) = 1.24, p = .222. Sense of presence scale: (M = 5.23, SD = 1.00) were also greater than the chance level of 4, t(43) = 8.23, $p <$ .001. Cybersickness: (M = 4.64, SD = 2.02) was also greater than the chance level of 4, t(43) = 2.09, p = .043. Moreover, results showed significant relationship between the sense of presence and the factor of ownership r (44) = .57, $p <$ .01, and location r (44) = .62, $p <$ .01, but not for agency r (44) = .26, p = .08 of the embodiment scale. The cybersickness correlate with ownership r (44) = .31, $p <$ .05. No significant relationship between SoE and other factors were found.

4. DISCUSSION

The preliminary results of the present work showed that the 360-degree immersive video could be an efficacious instrument to induce the body swap illusion from male to female body. Results showed that male participants had a significant high sense of location and ownership of the female body, but not a high sense of agency. The low score in this dimension of the SoE could be explained because the 360-degree video was pre-recorded, so participants simply followed the movements of the female performer, but they are not free to do the movements they want. Moreover, results showed that the sense of presence and the cybersickness play an important role on the sense of ownership, so the quality of the environment and the predisposition of the participants should be considered in studies based on the embodiment paradigm.

5. REFERENCES

Dewez D, Fribourg R, Argelaguet F, Hoyet L, Mestre D, Slater M, Lécuyer A (2019). Influence of Personality Traits and Body Awareness on the Sense of Embodiment in Virtual Reality. In 2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR) (pp. 123-134). IEEE.

Ehrsson HH (2007). The experimental induction of out-of-body experiences. Science, 37(5841), 1048-1048

Matamala-Gomez, M., Maselli, A., Malighetti, C., Realdon, O., Mantovani, F., & Riva, G. (2021). Virtual Body Ownership Illusions for Mental Health: A Narrative Review. Journal of Clinical Medicine, 10(1), 139.

Repetto C, Germagnoli S, Triberti S, Riva G (2018). Learning into the Wild: A Protocol for the Use of 360° Video for Foreign Language Learning. In International Symposium on Pervasive Computing Paradigms for Mental Health. Springer Cham, pp. 56-63. https://doi.org/10.1007/978-3-030-01093-5_8.

Interviewing a Virtual Patient: Exploring patterns in clinical interviewing of psychologists

S A Mansuklal[1], P Gamito[2], T Souto[3], R Conde[4]

[1,2] HEI-Lab: Digital Human-environment Interaction Lab, Lusófona University, Lisbon, PORTUGAL

[1,2] Faculty of Psychology and Life Sciences, Lusófona University,
Lisbon, PORTUGAL

[3,4] Faculty of Psychology, Education and Sports, Lusófona University of Porto,
Porto, PORTUGAL

[1] *shivanimansuklal98@hotmail.com*, [2] *pedro.gamito@ulusofona.pt*, [3] *p2683@ulp.pt,* [4] *p5025@ulp.pt*

[1, 2] *www.hei-lab.ulusofona.pt,* [1, 2] *www.ulusofona.pt,* [3,4] *www.ulp.pt*

ABSTRACT

Psychological evaluation and, specifically, clinical interview are recourses in psychology practice that require adequate skill training to simultaneously gather information while establishing a therapeutic relationship. Literature points out the use of virtual patients (VPs) as a potential tool for training these skills. This study attempts to identify the adequate procedure to conduct a clinical interview, with the purpose of developing a protocol for the first session for training of MSc students and/or junior psychologist trainees, and further apply this in the training of VPs. Focus groups were held with psychologists to validate the content of the clinical interview guide.

Keywords clinical interview, clinical case, training model, virtual patient, focus-group

1. INTRODUCTION

Psychologists' professional activity is essentially "the promotion of physical, psychic, and social wellbeing of persons, organisations, and communities" (OPP, 2016, p.18). Furthermore, evidence-based practice (EBP) – defined as "the integration of the best available research with clinical expertise in the context of patients characteristics, culture, and preferences" (APA, 2006, p. 273) – is essential in all activities of professional practice, including psychological evaluation. Considered one of the central competencies and most frequent activities in the professional practice of psychologists, psychological evaluation assumes the appropriate use of techniques and evaluation instruments, requiring specific competencies, although the judge and responsibility of these competencies is up to the professionals' self that undertakes great risks (OPP, 2011, 2016).

Psychological evaluation involves the integration of information from various sources beyond the application of psychological tests, for example history case, verbal and non-verbal behavioural observation, collateral reports and historical documents, and represents an initial phase of psychological practice (Groth-Marnat, 2003). Considered an exclusive act of psychology, it assumes the appropriate use of techniques and evaluation instruments requiring specific competencies acquired from updated personal and scientific experience and training according to theoretical and scientific assumptions which demonstrates the need for efficient teaching and training methods (OPP, 2016). The clinical interview is considered one of the most frequently used methods in psychological evaluation, which serves the purpose of establishing an empathetic relationship, obtaining information, evaluating psychopathology, providing feedback, conceptualising the problem(s), formulating hypotheses, selecting and defining therapeutic goals, and evaluating therapeutic processes and results, consequently affecting therapeutic success (Buela-Casal, 2004; Okamato, Dattilio, Dobson, & Kazantis, 2019). The model and degree of structure of the interview is presumed to influence the dialog during the interview, the course of the interview, and the register and interpretation of the information. Theoretical orientation and personal characteristics of the psychologist may also influence the achievement of the goals of the clinical interview, as may the use of basic interviewing techniques (Weiner, 2003).

In this sense it is necessary to use an adequate approach in training, as concerns regarding the influential factors of the interview arises. The psychologist must be competent in guiding the interview while gathering relevant information from different topics of the clinical history. Simultaneously, one must follow the thought process of the client with minimum intervention (Buela-Casal, 2004). The psychologist must also be competent in clinical observation, namely in verbal and non-verbal communication, to gather information for the mental state examination occurring throughout the duration of the interview (Correia & Paulino, 2014). Furthermore, empathetic commentaries and summarization can be perceived as positive, reinforcing perceived active listening and empathy (Sommers-Flanagan & Sommers-Flanagan, 2003). The use of basic interviewing techniques allows one to better conduct the interview in order to reach the main goals of the interview, and assumes the necessity of specific competencies for adequate use, for example regarding a relationship of trust between psychologist and client (Weiner, 2003a).

Psychotherapeutic skills do not have a scientifically based training model, resulting in the co-existence of several methodologies and criteria in the implementation of training programs and supervision (Allen, Littlefield, & Schmidt, 2018). Investigation on the efficacy of these different methods becomes quite challenging, especially in the use of adequate design methodologies, resulting in scarce and inconclusive results (Callahan & Watkins, 2018a, 2018b). From what is known regarding conventional training methods, role-playing is commonly used for evaluation and training of basic interviewing skills and use of basic interviewing techniques as it is done by direct observation (Barney & Shea, 2007). For healthcare students, this method has been proven to promote reflection, insight, and positive attitudes social norms and perception of behavioural control in training healthcare professionals in the evaluation of suicide (Rønning & Bjørkly, 2019; Grylewicz et al., 2019). However, a major disadvantage can be an unnatural interaction that may not be authentic and may not represent the possible challenges one may face in clinical practice. Additionally, there is less control of the course of the interview by a supervisor (Tufford, Asakura, & Bogo, 2018).

The use of standardised patients, a commonly used method for health care professionals, implicates the use of actors posed as patients, and is significant for evaluation and training of diverse skills for professional practice in healthcare, demonstrating facial validity and effectiveness in allowing learning and practice in a controlled environment (Künhe, Ay, Otterback, & Weck, 2018; Keiser & Turkelson, 2017). It is considered effective for the development of basic interviewing skills (Logie, Bogo, Regher, & Regher, 2013; Washburn, Bordnik, & Rizzo, 2016), communication skills (Neurderth et al., 2018) and clinical competence (Oh, Jeon, & Koh, 2015; Williams & Song, 2016). Disadvantages to the use of standardised patients are: financial cost; recruitment selection and training method; and human resources. In the same manner, it is challenging to enable a great diversity of simulated scenarios and an authentic portrayal of symptoms in a consistent manner (Keiser & Turkelson, 2017; Künhe, Ay, Otterback, & Weck, 2018; Parsons, Kenny, & Rizzo, 2008; Kenny, Rizzo, Parsons, & Gratch, 2007a). In this sense, a certain impossibility to present a completely controlled environment for training skills is evident (Stevens et al., 2006).

Virtual Reality (VR) has recently emerged in this context in different fields, namely medicine, nursing, social services, clinical psychology and psychotherapy, specifically for the evaluation and training of clinical reasoning skills (Forsberg, Ziegert, Hult, & Fors, 2016), skills in anamnesis and differential diagnosis (Maicher, Danforth, Price, & Zimmerman, 2017) and communication skills (Bracq, Michinov, & Jannin, 2019). In healthcare, VPs are potentialized as computerized interactive simulations for training, education and evaluation (Konowicz, et al., 2019), as they can replicate authentic and controlled interactions in virtual clinical scenarios while representing patients in a real manner. Advantages of using VR in training skills are: ecological validity in the use of instruments on the evaluation of professional competencies; immediate feedback of performance and efficiency during training (Parsons et al., 2008); and repeated practice in a safe environment with no real risk of prejudicial consequences in a real or even standardised patient (Stevens et al., 2006). Additionally, VPs enable an authentic portrayal of the clients' verbal and non-verbal behaviour (Kenny et al., 2007a). Specifically, in the context of mental health, the concept of interview skills is presented in second plane as the focus has been on development of realistic VPs (Parsons, Kenny, & Rizzo, 2008; Kenny et al., 2009; Kenny et al., 2007b). The application of the simulation method still requires the comprehension of a single and efficient training model that is not yet properly defined in psychology itself. It also requires understanding the process of the interview in clinical practice, that might help in the construction of a model (Callahan & Watkins, 2018a, 2018b).

Literature regarding this theme leads to the questioning of how the clinical interview should be conducted. In the present study, the goal is to develop a protocol for the first session of the clinical interview for pedagogical purposes in the training of Msc students and/or junior psychologist trainees, and to further apply this in the training with VPs. The methodological design is one of a qualitative approach, consisting in the use of focus groups with psychologists.

2. METHOD

2.1 Participants

The sample consisted of 2 groups of 3-4 psychologists, summing up to a total of 7 psychologists selected according to the convenience method. Inclusion criteria were clinical psychologists in Portugal with experience in the practice of psychological evaluation with adults.

2.2 Instruments

2.2.1 Focus group discussion guide. An orientation guide was elaborated to run the focus groups, and held various sections for discussion, namely: the adequacy and quality regarding the clinical interview guide and each section in detail; the adequacy and authenticity of the elements composing the clinical history case and of the dialog between psychologist-client; and a discussion of the proposal of the clinical interview guide and questions regarding the proposal for various disorders.

2.3 Procedure

The project was first presented at the ethics committee of the Faculty of Psychology and Life Sciences of Lusófona University in Lisbon, Portugal, for approval. Posterior to this process, potential participants were contacted and invited to collaborate in the study via e-mail by the investigators. A brief description of the study and additional information regarding the focus group, as well as the documents for the discussion were included in the e-mail. The informed consent was requested to be signed and sent to the investigators prior to the focus group, and contained matters regarding conditions for participation, confidentiality and authorization for video- and audio- recording. As responses were received, efforts were made to ensure that the focus groups were held in accordance to the participants' schedules. Given the Covid-19 Pandemic and associated contingency measures, the focus groups were held through the videoconferencing platform Zoom. All recorded sessions were eliminated after an *ipsis verbis* transcription for further analysis.

The focus group held various phases, namely the presentation of the investigators, group participants, the project and objectives, followed by the discussion of two documents – a clinical interview guide and a clinical history case. Regarding the documents, a Portuguese interview guide for behavioural evaluation (GEAC; Gonçalves, 1990) was adapted by the investigators of the study and used as a baseline for discussion, containing four main sections – initiation, global functioning, problematic areas, and finalisation. Each section contains themes that in itself contain questions or topics to be asked to the client. Additionally, following a literature review, a clinical history case that represents adjustment disorder was developed as a dialog of a possible verbal interaction between psychologist-client, respecting the items most commonly found in clinical cases. Both were distributed via e-mail for prior review on behalf of the participants.

2.4 Data Analysis

Content analysis was used as the study underlies a descriptive and exploratory nature. Following the steps and procedures suggested by Erlingsson and Brysiewicz (2017), an inductive logic permitted the continuous process of coding and categorization of the data from participants' reports. Software *Nvivo10* was used for the organization and codification of the data.

4. RESULTS

Given the objectives of the study, initially the results regarding the evaluation of the clinical interview guide are presented and, secondly, the evaluation of the clinical case. Regarding language purposes, the excerpts of the focus groups were translated for the purpose of this paper with great concern for authenticity insured by words and expressions used by the participants.

4.1 Evaluation of the clinical interview guide

Participants' reports in both focus groups regarding a general appreciation of the clinical interview guide was considered as mainly positive aspects of completeness and good structure, as the first focus group (FG1) considers "it seemed globally well to me in terms of organization. The guide has a family history, vocational, then has a professional history, relational to health history and developmental aspects" as the second focus group (FG2) refers "The guide is very complete, it's well structured. It focuses various different areas that are important to evaluate; I think it gives us a lot of information that, sometimes, we don't remember". Nonetheless, throughout the focus groups, several suggestions were made and discussed to further the adequacy of the guide.

Table 1. *Global appreciation of the clinical interview guide.*

	FG1	FG2
Positive aspects		
Complete and well structured	1[1]	4
Integrates the important areas in evaluation	1	4
Suggestions		
Reorder: motive – problematic areas – developmental aspects	11	17
Reformulate the questions – simpler and more adequate to the language of the client	10	3
Diminish the extension or necessity of more than one session or a longer one	3	6
Reformulate life competencies and developmental aspects, regroup repeated areas	1	7

[1] Number of references per category

Firstly, both focus groups consider a reorder of the sections of the clinical guide, respectively 'motive', 'problematic areas', and then 'developmental aspects'. Participants also suggest reformulating some questions in a simpler and more adjusted manner to the clients' language. Furthermore, it is consensual that questions from the 'life competencies' and 'developmental aspects' are the sections that are most in need of reformulation, respectively reorganization and regrouping to avoid repetition.

A more detailed analysis of each section was executed. The professionals recognised the pertinence and adequacy of the questions and made suggestions considering their professional experience. These suggestions are similar to the general appreciation, centred on: the reformulation to a simpler and flexible question format in regard to the case and responses of the client, and the reorganization of some sections.

Table 2. *Detailed analysis of the sections of the guide.*

Suggestions	FG1	FG2
Sociodemographic information		
Replace 'sex' by 'gender'	3	3
Global functioning		
Family History		
Put according to the case and include with whom you live and the family network	7	6
Do not detail the relationship and identification	1	2
Relational History		
Rephrase to current significant relationships (not exclusively romantic)	3	10
Withdraw or reformulate the number of relationships	3	1
Health history		
Focus on mental health	3	2
Reformulate or simplify to more open questions and include physical condition here	4	5
Developmental aspects		

Love, marriage, family, carreer		
Include, love, marriage, intimacy, in relational history and career in professional history	5	5
Competence, autonomy, values, identity		
Less specific, open and more flexible questions	6	24
Remove values	1	1
Life competencies		
Less detailed, more open questions	3	4
Remove values and specificity of group work and conflict	2	3
Problematic areas		
Add expectations relative to the treatment	1	3
Include emoticons and cognition components	2	1
Finalization		
More in-dept – explore goals and provide feedback	2	6

Firstly, regarding the sociodemographic information section, they suggest the replacement of the word ‘sex’ by ‘gender’. In the ‘global functioning’ area, the focus was on three specific sections. Considering ‘family history’, the indication is to contemplate constructing specific questions in function of the case of the client and to include questions about who they live with currently as well as the family network. However, both focus groups suggest refraining from detailing the type of relationship and to repress solicitating specifically, the identification of persons. For ‘relational history’, there is a need to reformulate questions in the sense of current significative relationships as opposed to exclusively intimate relationships. They also suggest removing or reformulating the question regarding the number of relationships. In ‘health history’, the inclusion of mental health, reformulating and simplifying questions to a more open format and inserting here the ‘physical health condition’ sub-section from the ‘life competencies’ section is also highlighted.

Both groups, for the ‘developmental aspects’ section, propose regrouping the subsections ‘love-marriage-intimacy’ into ‘relational history’ and moving ‘career’ to ‘professional history’ while avoiding repeating previously explored areas. The subsections ‘autonomy’, ‘competency’ and ‘identity’, necessitate less specificity and more open and flexible question and, additionally, participants suggested removing the ‘values’ sub-section. In the same sense, they highlight suggestions for ‘life competencies’, indicating less detail and open questions, as well as the removal of the question regarding values and the specificity in the group work and conflict questions so to not limit these aspects in the interpersonal relationship questions. Furthermore, recommendations for the ‘problematic areas’ sum up to addressing the expectation the client holds regarding the treatment and including the emotional and cognitive components to the problem beyond just the behavioural component already present. FG1

In the finalization phase, it is consensual that the objectives with the client be explored, and that the therapist provide feedback of the interview, as FG1 states “It would be this area to give some feedback”, and FG2 similarly adds “I think it might be important for the establishment of the therapeutic relationship to talk in this section about the therapeutic goals, the expectations for the treatment, to give some feedback about what was heard during that first session, to give space to the person to clarify something, to add something, to clarify any questions one might have about the session or the structure of the next”.

4.2 Evaluation of the clinical case for the VP

Both focus groups identify mostly positive aspects regarding adequacy and pertinence for student learning and training when it comes to the evaluation of the clinical case. FG1 mentions “from a pedagogical point of view, the choice of someone with this age helps the process of comprehension as well as the way how the answers are constructed. So, I think you can manage that the young person, usually young, gets familiar with these questions of initial interviews and that can understand the broad approach of what is intended. From a formative point of view, it is very adequate, the questions are quality questions and are well formulated, the way they should be formulated”, as FG2 denotes “For this case in particular, the guide ends up being pretty adequate. I think it is a good exercise. There is loads of work here and it is an extremely relevant work from the formation of students’ point of view. Many times, people feel extremely anxious to do the first interview with someone and so everything that can give structure, security, and training is good. It is an important basis of work, important from an academic point of view but also is important in the point of view of clinical practice".

Table 3. *Evaluation of the clinical case.*

	FG1	FG2
Positive aspects		
Adequate and pertinence for the training of students	4	6
Realistic replies from the client	7	1
Suggestions		
Feedback from the therapist throughout and at the end of the interview – validate the client	1	2
Semi structured guide with different possibilities of questions depending on the case	3	8

They also positively highlight the adequacy of the dialog constructed for the client. Despite this, they offer two suggestions that emerged from the discussion in the both groups and that might contribute to further the sense of realism of a session with the client. The first encounters the necessity to have some kind of feedback from the therapist throughout and at the end of the interview, as it is important to validate the report and experience of the clients, that is further acknowledged in previous literature. Furthermore, they consider the guide to be a semi-structured guide with different possibilities or ramifications of questions depending on the case.

5. DISCUSSION AND CONCLUSION

As VR enables the development of diverse applications for the training of essential skills needed in clinical and non-clinical contexts, the necessity to comprehend the process during the conduction of a clinical interview is still to be addressed and taking necessary steps in establishing a model for training clinical interview skills are to be made, as efforts to potentialize VPs in training psychotherapeutic and interview skills in students are scare (Latham et al., 2019). The current study represents a first step for validation of a pedagogical resource of clinical interview. Various themes identified by psychologists have contributed to the development of a clinical interview guide and clinical case, for the construction of an appropriate interaction with a VP.

Certain topics explored in the focus group are mentioned relatively broadly in literature concerning psychological evaluation. The focus groups resulted in several topics to have in account regarding how the clinical interview should be conducted and further contributed for the validation of a clinical interview guide and a clinical case for the construction of a VP for student training. Generally, the clinical interview guide is considered complete and covers all important areas to explore in a clinical interview. The main suggestions were towards ameliorating the guide, with modifications in the order of the sections, and regrouping questions, in order to diminish the repetitive nature of the guide and extension of the interview so to be executed in just one session, and also reformulating questions to be more open and flexible. Additionally, the inclusion of the emotional and cognitive components was pointed out, that are compliant to the cognitive-behavioural model, as it holds a more significant expression in empirically validated interventions.

Regarding the discussion of a semi-structured format of the guide, it was considered the most adequate form for information-gathering as it allows a guided but flexible exploration (Buela-Casal, 2004). In this sense, the validation of the guide considered the value of a flexible guide according to the client, as initially intended. However, interesting suggestions of a flowchart for a personalised alignment of the questions of the interview was considered. Future studies may consider the utility of the development of a flowchart as a branch-like decision-making system, that provides the opportunity for the trainee to learn through multiple-choice options of verbal interaction with the VP, while receiving feedback from the system itself regarding the adequacy of the options. Regarding the clinical case, it may need adjustments to adapt to the suggested modifications. As progress is made on the guide and the clinical case, we identify the need to promote a future focus group in order to produce a definitive guide to be used with a VP, that will then be presented to students who may also integrate a focus group to contribute to the validation of the applied guide and VP as a pedagogical resource in students training.

This study intends to be the first step to understand the adequate procedure to conduct clinical interviews, specifically by validating the areas and topics that should be addressed during a first session for future training of psychology students. Another concern was related to the realism of the script for the VP. This study presents some limitations regarding procedures: (1) a non-limiting inclusion criteria allowing a diverse sample of clinical psychologists with different theoretical orientations and/or with area- or population-specific experience may have not facilitated the level of accordance regarding certain topics of discussion; (2) the lack of a prior exploration of the topics to address during a first session of psychological evaluation in accordance to the psychologists experience may have limited the psychologists to only regard topics validating a general clinical interview guide without freely considering all important aspects of a psychological evaluation, for example, exploration of the types of basic techniques used during a clinical interview. In turn, future studies should still address other important aspects regarding the interview that need to be explored such as, basic techniques and clinical observation, verbal and non-verbal wise, with the same method of the current study. VR may further potentialize studies regarding the skills of the assessment of a patients' non-verbal behaviour and other aspects of the process of the clinical interview.

Acknowledgements: This study is funded by the Foundation for Science and Technology – FCT (Portuguese Ministry of Science, Technology and Higher Education), under the grant UIDB/05380/2020

7. REFERENCES

Allen, JV, Littlefield, AK, and Schmidt, AT, (2018), Developing a science of training in health service psychology: Contextual factors and recommendations for improvement, *Training and Education in Professional Practice*, **21**, *4*, pp. 262–268.

American Psychological Association, (2006), "Presidential Task Force on Evidence-Based Practice", Evidence-based practice in psychology, *American Psychologist*, **61**, *4*, pp. 271-285.

Barney, C, and Shea, SC, (2007), The art of effectively teaching clinical interviewing skills using role-playing: a primer, *Psychiatr Clin North Am,* **30**, *2*, pp. 31–50. doi: 10.1016/j.psc.2007.03.001

Bracq, MS, Michinov, E, and Jannin, P, (2019), Virtual reality simulation in nontechnical skills training for healthcare professionals: a systematic review, *Simulation in Healthcare*, **14**, *3*, pp. 188–194. doi: 10.1097/SIH.0000000000000347

Buela-Casal, G, (2004), *Manual de evaluación y tratamientos psicológicos*, Biblioteca Nueva.

Callahan, JL, and Watkins, CE, (2018a), Evidence-based training: the time has come, *Training and Education in Professional Psychology*, **12**, *4*, pp. 211–218. doi: 10.1037/tep0000204

Callahan, JL, and Watkins, CE, (2018b), The science of training II: prepracticum and practicum training, *Training and Education in Professional Psychology*, **12**, *4*, pp. 231–244. doi: 10.1037/tep0000209

Correia, DT, and Paulino, M, (2014), Entrevista e história psiquiátricas. In *Manual de Psicopatologia* (DT Correia DT, Ed), Lidel – Edições Técnicas, Lda., Lisbon, pp. 97–137.

Erlingsson, C, and Brysiewicz, P, (2017), A hands-on guide to doing content analysis, *African Journal of Emergency Medicine*, **7***,* pp. 93-99. doi: dx.doi.org/10.1016/j.afjem.2017.08.001

Forsberg, E, Ziegert, K, Hult, H, & Fors, U, (2016). Assessing progression of clinical reasoning through virtual patients: an exploratory study, *Nurse Education in Practice*, **16**, *1*, pp. 97–103. doi: 10.1016/jnepr.2015.09.006

Gonçalves, OF, (1990), *Terapia comportamental – modelos teóricos e manuais terapêuticos*, Edições jornal de psicologia, Porto.

Groth-Marnat, G, (2003), *Handbook of Psychological Assessment*, Wiley & Sons Inc., New Jersey.

Gryglewicz, K, Monahan, MM, Chen, JI, Bozzay, M, …, and Karver, MS, (2019), Examining the effects of role play practice in enhancing clinical skills to assess and manage suicide risk, *Journal of Mental Health*. doi: 10.1080/09638237.2018.15211936

Keiser, MM, and Turkelson, C, (2017), Using students as standardized patients: Development, implementation, and evaluation of a standardized patient training program, *Clinical Simulation in Nursing*, **13**, *7*, pp. 321–330. doi: 10.1016/j.ecns.2017.05.008

Kenny, P, Rizzo, A, Parsons TD, and Gratch, J, (2007a), Virtual patients for clinical therapist skills training. In *International Workshop on Intelligent Virtual Agents*, Berlin, Springer, pp. 197-210.

Kenny, P, Rizzo, A, Parsons TD, and Gratch, J, (2007b), A virtual human agent for training novice therapist clinical interviewing skills, *Annual Review of CyberTherapy and Telemedicine*, **5**, pp. 81–89.

Kenny, PG, Parsons, TD, Rothbaum, BO, Difede, J, Reger, G, and Rizzo, A, (2009), Optimizing clinical training for the treatment of PTSD using virtual patients, *Studies in health technology and informatics*. doi: 10.3233/978-1-60750-017-9-264

Künhe, F, Ay, DS, Otterback, MJ, and Weck, F, (2018), Standardized patients in clinical psychology and psychotherapy: a scoping review of barriers and facilitators for implementation, *Academic Psychiatry*, **42**, *6*, pp. 773–781. doi: 10.1007/s405960180886-6

Konowicz, AA, Woodham, L, Edelbring, S, Stathakarou, N, Davies, DA, Saxena, N, …, and Zary, N, (2019), Virtual patient simulations in health professions education: Systematic review and meta-analysis by the Digital Education Collaboration, *Journal of Medical Internet Research*, **21**, *7*. doi: 10.2196/14676

Latham, K, Kot, P, Wariach, A, Al-Jumeily, D, Puthuran, M, and Chandran, A, (2019), A review on the development of a virtual learning environment for medical simulation and training, *4th Int. Conf. on Appl. And Syst. Of Vis. Parad,* Rome, Italy.

Logie, C, Bogo, M, Regher, C, and Regher, G, (2013), A critical appraisal of the use of standardized client simulations in social work education, *Journal of Social Work Education*, **4**, *1*, pp. 66–80. doi: 10.1080/10437797.2013.755377

Maicher, K, Danforth, DR, Price, A, and Zimmerman, L, (2017), Developing a conversational virtual standardized patient to enable students to practice history taking skills, *Simulation in Healthcare*, **12**, *2*, 1. doi: 101097/SIH.0000000000000195

Oh, PJ, Jeon, KD, and Koh, MS, (2015), The effects of simulation-based learning using standardized patients in nursing students: a meta-analysis. doi: 10.1016/j.nedt.2015.01.019

Okamato, A, Dattilio, FM, Dobson, KS, and Kazantis, N, (2019), The therapeutic relationship in cognitive-behavioural therapy: Essential features and common challenges, *Practice Innovations*, **4**, *2*, pp. 112-123. doi: 10.1037/pri0000088

Ordem dos Psicólogos Portugueses (OPP), (2016), *Regulamento Geral de Especialidades Profissionais da Ordem dos Psicólogos Portugueses*, Diário da República, 2nd series (nº107-A/2016 on 29th January 2016), available in https://www.ordemdospsicologos.pt/pt/especialidades

Ordem dos Psicólogos Portugueses (OPP), (2011), *Code of Ethics*, Diário da República, 2nd series (nº 258/2011 on 20th April 2010), available in https://www.ordemdospsicologos.pt/en/documentos

Parsons, TD, Kenny, PG, and Rizzo, A, (2008), Virtual human patients for training of clinical interview and communication skills.

Rønning, SB, and Bjørkly, S, (2019), The use of clinical role-play and reflection in learning therapeutic communication skills in mental health education: an integrative review, *Advances in medical education and practice*, **10**, pp. 415–425. doi:10.2147/AMEP.S202115

Sommers-Flanagan, J, and Sommers-Flanagan, R, (2003), *Clinical Interviewing*, John Wiley & Sons, New Jersey.

Stevens, A, Hernandez, J, Johnsen, K, Dickerson, R, Raji, A, Harrison, C, …, and Lind, DS, (2006), The use of virtual patients to teach medical students history taking and communication skills, *American Journal of Surgery*, **191**, *6*, pp. 806–11. doi: 10.1016/j.amjsurg.2006.03.002

Tufford, L, Asakura, K, and Bogo, M, (2018), Simulation versus role-play: Perceptions of prepracticum BSW students, *The Journal of Baccalaureate Social Work*, **23**. doi: 10.18084/1084-7219.23.1.249

Washburn, M, Bordnick, PS, and Rizzo, A, (2016), A pilot feasibility study of virtual patient simulation to enchance social work students' brief mental assessment skills, *Social Work In Health Care*, **55**, *9*, pp. 1–19. doi: 10.1080/00981389.2016.1210715

Weiner, IB, (2003), *Assessment Psychology*, John Wiley & Sons, New Jersey.

Williams, B, and Song, JJY, (2016), Are simulated patients effective in facilitating development of clinical competence for healthcare students? A scoping review, *Advances in Simulation*. doi: 10.1186/s41077-016-0006-1

Construction and Effect of Relationships with Agents in a Virtual Reality Environment

Tiago Abril[1], Jorge Oliveira[2], Pedro Gamito[3], Mauro Bianchi[4]
[1,2,3,4]Escola de Psicologia e Ciências da Vida, Universidade Lusófona de Humanidades e Tecnologias
Campo Grande, Lisbon, PORTUGAL

[1]*tmcsabril@gmail.com*, [2]*jorge.oliveira@ulusofona.pt*, [3]*pedro.gamito@ulusofona.pt,* [4]*p4867@ulusofona.pt*

[1,2,3,4]*www.ulusofona.pt*

ABSTRACT

Recently studies have been focusing on behaviour changes (of approach and avoidance) towards agents in virtual reality. This paper aims to explore cognitive construction of a complementary relationship with an agent in virtual reality through a brief interaction in a virtual task. An experimental study was conducted through a brief interaction in a virtual task. Results suggest the importance of cognitive flexibility and complementary anthropomorphic projection of the agents in the construction of a relationship with a virtual agent. Findings also contribute to creation and use of virtual reality tools based on communication in a function-led approach, as well imply a critical view of models and scale to assess anthropomorphism and complementarity in virtual reality.

1. INTRODUCTION

The usefulness of virtual reality (VR) is already proven in terms of neurocognitive training (Gamito et al., 2019; Oliveira et al., 2017), highlighting not only results, but also the bet on ecological validity at the methodological level, focusing on a function-led approach, and not only on the typical construct-driven, psychometric approach (Gamito et al., 2016; Oliveira et al., 2014, 2017).

However, although the relevance and impact of the possible use of virtual agents (VA) is highlighted at the level of communication systems adapted to health, education, and management (Bailenson, 2018; Fox et al., 2015; Shriram, Oh & Bailenson, 2017), there are no studies or methods applicable to the level of neurocognitive training and clinical cyber therapy regarding communication disorders with cognitive origin or to intervene at the level of interpersonal relations.

A solution to this gap can be achieved by using non-player characters (NPCs) (Bender & Spat-Lemus, 2019; Daher et al., 2017a; Rosenfield et al., 2019).

The main objectives were: (1) to identify whether cognitive flexibility influences the anthropomorphic and complementary construction of an NPC; (2) to identify whether cognitive flexibility influences the construction of relationship with an NPC; (3) to identify whether the nature of VAs is anthropomorphized and perceived as complementary in relationships; and (4) to identify whether there is a greater emotional response, through skin conductance level, in the groups that interact with the agent.

2. METHOD

A sample of 53 adult participants with or attending higher education was studied, divided into a control group of 20, and two experimental groups, one of 20 and another of 13 participants.

The first experimental group interacted with a virtual agent through the Oculus Rift equipment, knowing that it was a non-player character (NPC) that communicated verbally. The second group interacted with the same virtual agent but was informed that it was an avatar controlled in real time by another person. In the present study, a neuropsychological assessment instrument for cognitive flexibility (Wisconsin Card Sorting Test), an instrument for measuring dermal conductance (using OpenSignals and SuperLab), an instrument for evaluating relational models (Modes of Relationships Questionnaire) and two instruments were created to assess the complete anthropomorphic perception of the virtual agent.

3. RESULTS

Results confirmed an effect of cognitive flexibility on the anthropomorphic and complementary perception of NPCs and on the application of relational models towards NPCs. An effect of the nature of the agents (NPC vs Avatar) in the application of relational models being mediated by the complementary anthropomorphic projection of the agents. The previous interaction with the virtual agent, perceived as an NPC, showed faster skin conductance responses with images of the NPC.

4. CONCLUSIONS

These results are of great relevance in the development of methods that facilitate the use and adequacy of virtual agents at the training level, not only neurocognitive, but also in the psychiatric scope.

The present study contributed to the understanding of the impact of cognitive flexibility in the construction of a complementary relationship with a VA. This allows to enhance the production of tools and methods in VR of neurocognitive training, with ecological validity and aiming at a function-led approach in terms of communication.

5. REFERENCES

Bailenson, J. (2018). Protecting nonverbal data tracked in virtual reality. JAMA Pediatrics, 172(10), 905-906.

Bender, H. A. & Spat-Lemus, J. (2019). Cognitive training and rehabilitation in aging and dementia. In: Ravdin L., Katzen H. (eds) Handbook on the Neuropsychology of aging and dementia. Clinical handbooks in neuropsychology. Springer, Cham.

Daher, S., Kim, K., Lee, M., Bruder, G., Schubert, R., Bailenson, J., & Welch, G. (2017a, March). Can social presence be contagious? effects of social presence priming on interaction with virtual humans. Communication presented in 2017 IEEE Symposium on 3D User Interfaces (3DUI), Los Angeles, USA.

Fox, J., Ahn, S. J., Janssen, J. H., Yeykelis, L., Segovia, K. Y., & Bailenson, J. N. (2015). Avatars versus agents: A meta-analysis quantifying the effect of agency on social influence, Human–Computer Interaction, 30(5), 401-432.

Gamito, G., Morais, D., Oliveira, J., Lopes, L., Picareli, L., Matias, M., ... Brito, R. (2016). Systemic lisbon battery: Normative data for memory and attention assessments. JMIR Rehabilitation and Assistive Technologies, 3, 1:e5.

Gamito, P., Oliveira, O., Morais, D., Coelho, C., Santos, N., Alves, … Brito, R. (2019). Cognitive stimulation of elderly individuals with instrumental virtual reality-based activities of daily life: Pre-post treatment study. Cyberpsychology, Behavior, and Social Networking, 22(1), 69-75.

Oliveira, J., Gamito, P., Morais, D., Brito, R., Lopes, P., & Norberto, L. (2014). Cognitive assessment of stroke patientswith mobile apps: A controlled study. Annual Review of Cybertherapy and Telemedicine, 103-107.

Oliveira, J., Gamito, P., Alghazzawi, D. M., Fardoun, H. M., Rosa, P. J., Sousa, T., ... Lopes, P. (2017). Performance on naturalistic virtual reality tasksdepends on global cognitive functioning as assessed via traditional neurocognitive tests. Applied Neuropsychology: Adult.

Rosenfield, N., Lamkin, K., Re, J., Day, K., Boyd, L., & Linstead, E. (2019). A virtual reality system for practicing conversation skills for children with autism. Multimodal Technologies Interact, 3, 28.

Shriram, K., Oh, S.Y., & Bailenson, J. N. (2017). Virtual reality and prosocial behavior, in Burgoon, J.K., Magnenat-Thalmann, N., Pantic, M. & Vinciarelli, A. (Eds.), Social signal processing (304-316). Cambridge University Press, Cambridge.

Tele-guidance based Remote Navigation Assistance for Visually Impaired and Blind People – Development and User Experience Findings

Babar Chaudary[1], Sami Pohjolainen[2], Saima Aziz[3], Leena Arhippainen[4], Petri Pulli[4]

[1]OASIS Research Group, [4]INTERACT Research Group, Information Technology and Electrical Engineering Faculty, University of Oulu, Pentti Kaiteran katu 1, P.O. Box 8000, FI-90014, Oulu, FINLAND

[1]*babar.chaudary,* [4]*leena.arhippainen,* [1]*petri.pulli @oulu.fi,* [2]*sami.pohjolainen,* [3]*saimaaziz01@gmail.com*

[1,2,4]*www.oulu.fi*

ABSTRACT

This paper reports the development of a specialized tele-guidance-based navigation assistance system and results of user studies conducted with eleven blind and visually impaired people (VIP) who were assisted in navigation by a remote sighted caretaker through it. The navigation scenario was tested with two alternative haptics methods for directional guidance using 1) two vibrating actuators, and 2) one vibrating actuator with differentiating vibration patterns for different cues. The results of the study showed a positive feedback from blind and VIP towards the proposed navigation assistance. From two alternate haptics actuator guiding methods, full blind subjects preferred one with two actuators, while partially blind/VIP preferred one using single actuator.

Keywords: Visual Impairment, Navigation, Remote Assistance, Haptics, User Experience, 4G

1. INTRODUCTION

Estimates from recent studies on global health show that 217 million people suffer from visual impairment, and 36 million from blindness (WHO, n.d.). The affected ones have their autonomy compromised in terms of everyday tasks, with the emphasis on activities that involve moving through an unknown environment (Golledge et al., 1996). The ability to explore neighborhood independently and to travel to a desired destination is required for a satisfactory level of quality of life and independence (Tverky, 1993). Although VIP and blind people learn navigation and orientation techniques through special training but it has been reported that thirty percent of them never leave their homes alone (Clark-Carter et al., 1986; White & Grant, 2009). Moreover, only a fraction of VIP and blind people travel independently to unknown destinations (Golledge, 1999). It is important to notice that the percentage of VIP and blind who never undertake a travel alone has remained unchanged in decades, despite the fact that more and more advanced assistive tools have become available (Balata et al., 2015). Blind and VIP frequently require assistance from other people in order to do daily chores of life, especially when navigating to unknown places. The problem often is that a person acting as a caretaker might not be always physically available for assistance. Recent technological advancements and miniaturization of electronics has enabled development of real-time sight-based guidance systems through audio and video communication remotely over the Internet.

This paper presents development of a specialized tele-guidance based navigation assistance system and results of field tests conducted with it eleven blind and VIP, who were assisted in navigation by a remote sighted caretaker. The results of the study showed a positive attitude from blind and VIP towards the proposed navigation assistance. From the two alternative haptic actuator guiding methods, full blind subjects preferred the one with two actuators, while partially blind/VIP the one using a single actuator with vibrating patterns for directional guidance. In the next chapter we briefly introduce the related work. The chapter 3 presents the system design, chapter 4 usability testing and UX study. In the chapter 5, results are presented and discussed. Chapter 6 presents conclusion, and finally chapter 7 presents Future work.

2. RELATED WORK

Research efforts of developing electronic travel aids (ETA) for blind and visually impaired span over 70 years. Earlier devices were designed for obstacle avoidance using sonar and laser technology. User interface (UI) for those devices were based on either vibration or sound (National Research Council, 1986; Benjamin, 1974]. By 80s, researchers were able to add computation capabilities to their artefacts to further expand the range of relayed assistance information by filtering and processing input data and improved UIs (Maude et al., 1983). Arrival of global navigation satellite systems (GNSS), specifically the Global Positioning System (GPS) in 1996 made it possible help blind and VIP reach a destination independently. Products like Trekker, BrailleNote GPS, Drishti and others related abruptly became available in the market and location-based technology became the backbone of navigation assistance systems (Library of Congress. n.d.; Humanware, n.d.; Ponchillia, 2007; Helal et al., 2001).

There are various situations where technology fails to ensure reliable and consistent support (e.g., crowded spaces, indoors, construction areas) (Williams et al., 2013). Remote assistance systems in research been developed to provide many kinds of support but remote navigation assistance is been most addressed problem. That is because navigation and mobility are primary elements of human independence.

MOBIC project was one of the earlies research projects for remote navigation assistance to blind and VIP. The navigation assistance was provided verbally using GIS and GPS (Petrie et al., 1997). Garaj et al. (2003) developed a remote navigation assistance system through which, one way real time navigation assistance was provided using video feed from digital camera carried by blind and VIP, GPS, GIS data through remote assistant using personal computer. Bujacz et al. (2008) developed a prototype through which remote assistant provide navigation assistance using video stream through a USB camera and two notebook computers for wireless internet connectivity. Testing of the prototype was done in a controlled indoor setting. A more advanced version of this system was developed and evaluated by Baranski & Strumillo (2015). The evaluation was done in real world setting. The results findings showed ineffectiveness of the system at busy crossing without traffic lights and low video quality at day time.

Number of commercial applications are available now to provide sighted guidance of remote crowd-sourced caretakers/volunteers to VIP and blind people. Be My Eyes is one such well-recognized example through which, a blind/VIP can establish a video connection with crowdsourced volunteers who assist by seeing live video feed as conversational question-answering assistants (Be My Eyes, n.d.). The volunteer assistants provide almost real time assistance by interpreting the video feed from the users' smartphone camera. There are many benefits of using crowd sourcing assistants, yet quality assurance is an issue in this service that has been reported by studies (Avila et al., 2016). In an effort to overcome quality assurance issue, a collaborative assistance platform called Aira introduced human agents concept whom are dually trained about etiquettes and vocabulary of communication principles (Aira, n.d.). VizWiz (n.d.), TapTapSee (n.d.), and BeSpecular (n.d.) are also some examples of such commercial platforms that have demonstrated the idea of crowd workers responding to photos or videos captured by the users' camera so that they can flexibly query for real-time assistance in a variety of situations.

3. SYSTEM DESIGN

In this chapter, we describe the developed tele-guidance based navigation assistance system, which comprises of the following components: Smart Cane, Mobile application, and Web Server (Fig. 1).

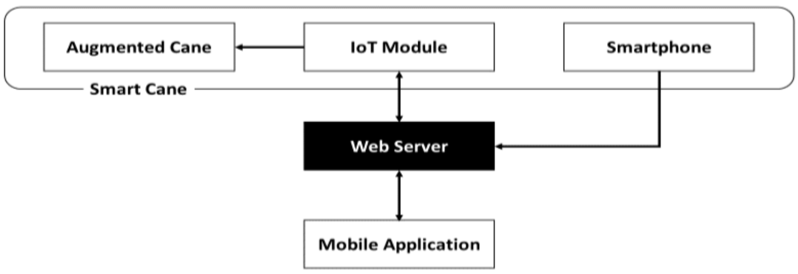


Figure 1. *Block Diagram of Navigation System*

3.1 Smart Cane. Smart Cane comprises of four components: Augmented Cane, IoT Module, Smart Phone, and Bluetooth earpiece.

3.1.1 Augmented Cane. Augmented cane is an ordinary white cane which grip is enhanced with a tactile user interface (UI) comprising of two alternate haptics schemes, Fig2. One haptics scheme has two adjacent vibrators installed in parallel. While second haptics scheme utilizes one vibrator. With two vibrators' scheme, user need to move left or right based on which side vibrator is vibrating. While with one vibrator, patterns are used for direction guidance. If vibrator vibrates brief one time, user moves right. While if it vibrates three times in quick successions, user needs to move left. UIs are installed on opposing sides of the grip. UI has open connections for it to be attached to IoT module to receive vibration control relay. Since Augmented Cane is developed using a modular approach, it can be connected to other sources of input too.

3.1.2 IoT Module. The IoT module is a custom made removable module that is attached to augmented cane, Fig3. It's connected to tactile user interface through wired connection. The circuitry of the chip is controlled by an Arduino MKR1010 MCU [Arduino MKR 1010]. It has WI-FI and BLE (Bluetooth Low Energy) connectivity. It's connected to the web server through Wi-Fi.

3.1.3 Smart Phone. A smart phone is hanged in the neck of blind or VIP through a necklet to send real time video feed of field of view of carrier to remote caretaker.

3.1.4 Bluetooth Earpiece. Bluetooth earpiece are used for voice communication with remote caretaker.

3.2 Mobile app. The remote caretaker's terminal is a mobile application (Fig. 4), which is developed by using Blynk IoT library [Blynk]. Its user interface has a window on top that shows live video feed of the field of view of the test subjects. It has two button at the bottom to control the vibrators on tactile user interface of the Smart Cane. It also enables voice communication that uses separate GSM channel to remove delay in communication that may be caused by IoT communication. The video feed has a lag while voice communication is real time.

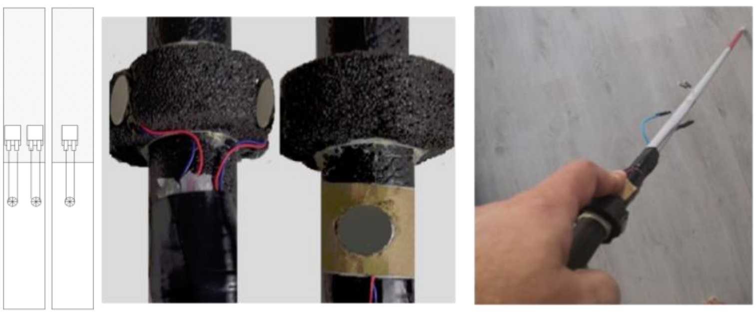


Figure 2. *Augmented Cane*

Figure 3. *IoT Module*

3.3 Web Server. The web server hosts the control logic of the communication between Mobile App and IoT Module. It is a cloud hosted development server provided as a service by the Blynk IoT library.

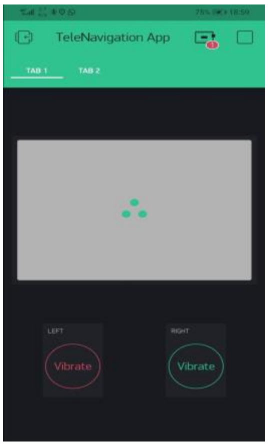


Figure 4. *The user interface of the Remote Caretaker's mobile application*

4. UASABILITY TESTING AND USER EXPERIENCE STUDY

This chapter presents the testing sessions where, the system was tried by real blind and VIP subjects with the help of a sighted remote caretaker who navigated them on a planned route. The aim of the study was to validate system design and investigate which of the two alternative haptics guidance schemes was preferred by the test subjects.

4.1 Experiment setting

4.1.1 Participants. The user experience study was conducted with 11 visually impaired participants, whose mean age was 32 and median 35. We had 3 females and 8 males. Participants were recruited through direct contact to blind associations in Pakistan. The links to the blind association were already established as they were the recruitment sources in earlier studies. The caretaker was a sighted female (38 years) who has worked in our research group. Table 1 describes participants' the category of visual impairment, gender and age.

Table1. *Onset of the impairment (congenital – C, late – L), category of visual impairment (B1-No light perception, B2-Ability to recognize the shape of a hand [USAB]), gender, and age.*

Participants	ID1	ID2	ID3	ID4	ID5	ID6	ID7	ID8	ID9	ID10	ID11
Onset	C	C	L	L	C	C	C	L	L	L	C
Category	B1	B2	B1	B2	B1	B2	B1	B2	B2	B2	B1
Gender	F	F	F	M	M	M	M	M	M	M	M
Age	21	21	23	47	36	23	38	44	35	29	44

4.1.2 Equipment. Equipment used in the experiment consisted of smart cane, a portable 4G Wi-Fi router, a smart phone Huawei Honor 8 [Huawei Honor 8] hanged through necklet in the neck of blind/VIP test subject and a big screen smart phone Galaxy Note 10 [Samsung Galaxy 10] as remote caretaker's terminal.

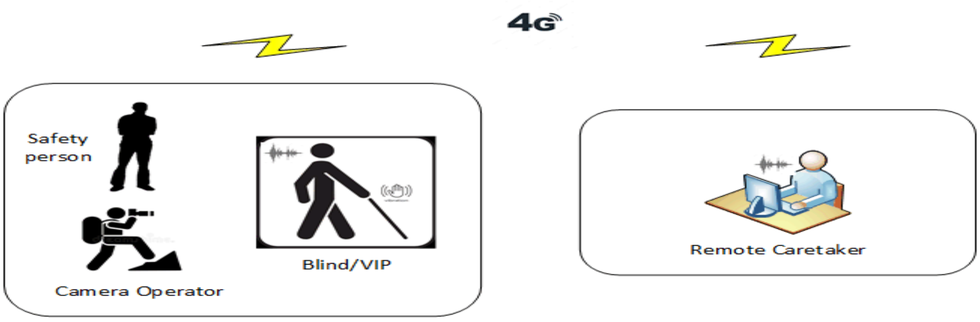


Figure 5. *The navigation test scenario*

4.1.3 Route. The experiment was conducted both in indoor and outdoor environment. The outdoor testing place was inside a public park where it was possible to do testing with less interference and hazards (Fig. 6). The indoor rout was a corridor in a building. Outdoor route had 8 decision points while indoor had 10 decision points. The length of indoor route was 150 feet and outdoor route was 250 feet.

4.1.4 Training and Navigation Protocol. Before starting the testing session, participants were given an oral introduction about the system and test procedure. The Smart Cane was handed over to them to get a feel of it. Any questions asked were answered. While at the start of the session, approximately 5 minutes were used to have a test run of the system by giving few tactile cues and voice commands to get test subject familiar with system and confirm working of the equipment. An important piece of protocol was how to act upon while taking a turn using vibrational cues. In the case of two vibrators UI, participants need to turn until they feel the vibration. While in the case of one vibrator using patterns, with one time vibrational cue, they need to turn 45 degrees and wait, if they do not receive a tactile cue again, they start walking.

4.1.5 The Experiment. The experiments consisted of three sessions. One session was indoor and two sessions were outdoor. Each session was conducted involving four persons: a remote caretaker, a blind/VIP test subject, a camera operator, and a safety guy for test subjects (Fig 5). Each session lasted around 45 minutes including navigation and interview. Tactile communication was used as primary navigation assistance. Voice commands were used as secondary navigation assistance method not to engage test subjects auditory senses unnecessary. After giving start cue, voice commands were used only if it was felt by caretaker that test subject is missing the tactile commands due to technical reasons or misread. At the start of the experiment, the remote caretaker described the field of view to the test subject and asked him to start navigation while following the tactile directional cues from vibrators. The remote caretaker directed the test subject by providing assistance using vibrators to take a direction on a decision point or being oriented on the track.

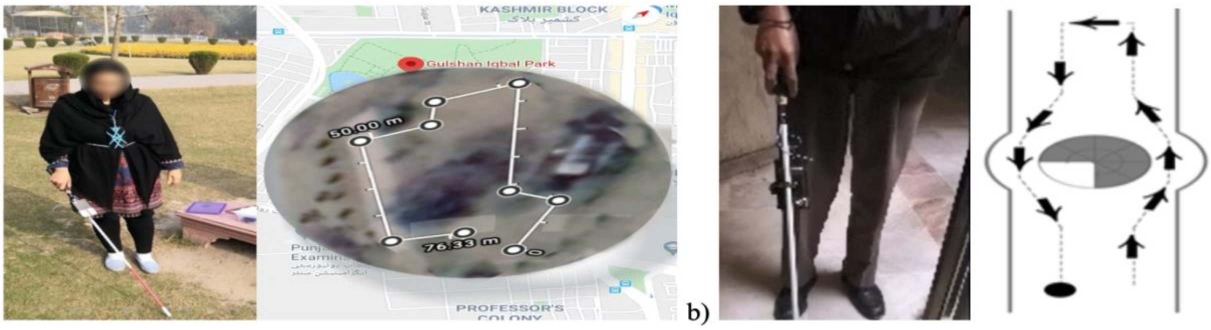


Figure 6. *The navigation task in the a) outdoor and b) indoor experiment setting*

The navigation scenario was tested with both haptics vibrations scheme separately. All tests were video recorded for observation. After completion of each scenario, after scenario questions were asked and audio recorded. Users' cumulative feedback about usability and acceptance of the system was asked and audio recorded at the end of the test. Further interviews about UX were conducted using a meCUE 2.0 based questionnaire and were marked on a paper sheet. All questioning, assisting, and data gathering was conducted in native language of the users. The data gathering was based on field laboratory design recommendations by (Høegh et al., 2008).

5. RESULTS AND DISCUSSION

After analysis of the testing videos, feedback interviews, and background data, the results of the users' study are summarized in table 2. The preference of user interface scheme by test subjects is categorized under eight groups that share similar characteristics. The results of the testing shows that default choice of full blind subjects (B1) is two vibrators user interface scheme while one vibrator for VIP. After observation and discussion with test participants, this behavior is rationalized as while full blind subjects have full concentration on cane when navigating, it was easy for those to understand instruction from two vibrators. Few even suggested an additional 3rd vibrator to give them haptics cues to stop or start again. While in the case of VIP subjects (B2), as they have some vision left which they try to use in some way during navigation, that keep their attention diverted on others things too other than cane. It is easy for them to get instruction from one vibrator than two as mental load is less in this case. These are the cases with a regular cane user. While if there is a test subject who is not a regular cane user or never used a cane before, than age becomes a factor. The young ones (under 24 in our case, needs further study), whether blind or VIP prefer two vibrators as they have capacity to learn the skill. While aged subjects both blind and VIP with no or little cane experience, find it easy to learn using one vibrator. Table 2 describes this choice phenomenon with all cases.

Table 2. *Preferences of user interface schemes by group of test subjects*

User Characteristics			*Response*	
Full Blind or VIP	**Regular Cane User**	**Age <= 24**	**1st Preference**	**2nd Preference**
Blind	Yes	Yes	Two Vibrator	One Vibrators
Blind	Yes	No	Two Vibrator	One Vibrators
Blind	No	Yes	Two Vibrator	One Vibrators
Blind	No	No	One Vibrators	Two Vibrator
VIP	Yes	Yes	One Vibrators	Two Vibrator
VIP	Yes	No	One Vibrators	Two Vibrator
VIP	No	Yes	Two Vibrator	One Vibrators
VIP	No	No	One Vibrators	Two Vibrator

VIP participants' user experiences collected via meCUE 2.0 questionnaires (Fig. 7) shows a positive feedback towards the proposed navigation assistance. They perceived the system as useful and usable (Module I). Also overall evaluation of the system was high (mean value 4,4). Cronbach Alpha test was used to check the consistency of the user response data Fig 8 shows the results. All values of Cronbach alpha reliability test results are ranging from 0.73 to 0.86. A general rule of thumb is that a Cronbach's alpha of 0.70 and above is good. All the indicators on this research which are measured by the questions can be said that all indicators on the research are reliable.

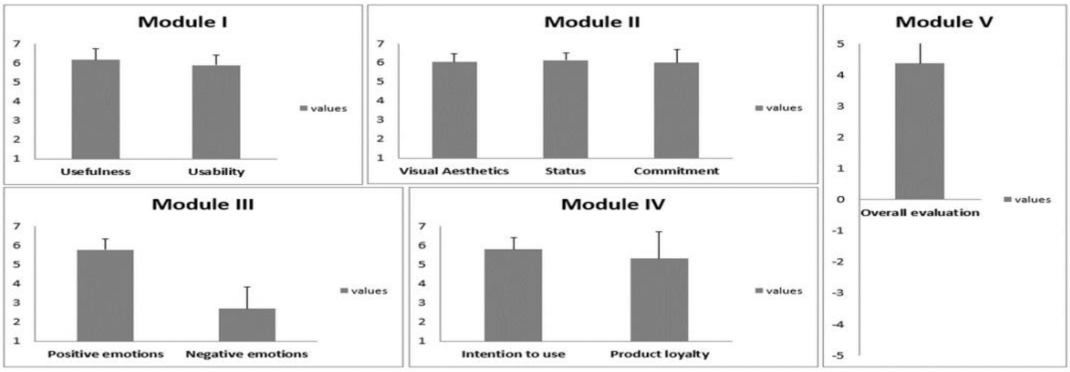


Figure 7. *Mean values and standard deviations according to meCUE 2.0 questionnaires*

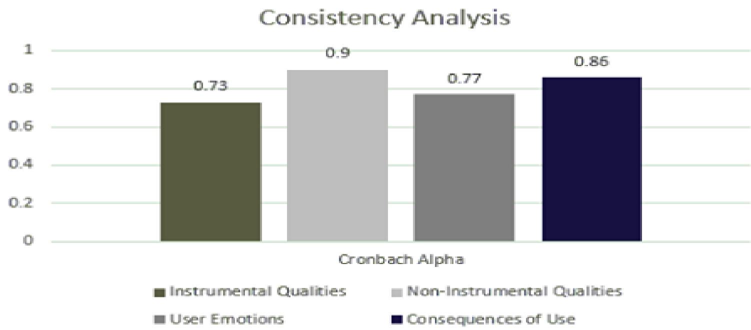


Figure 8. meCUE 2.0 questionnaire response consistency analysis results

6. CONLUSIONS

This paper reports the development of a specialized tele-guidance-based navigation assistance system and results of field tests conducted with eleven blind and visually impaired people who were assisted in navigation by a remote sighted caretaker through it. The navigation scenario was tested with two alternative haptics methods for directional guidance using 1) two vibrating actuators, and 2) one vibrating actuator with differentiating vibration patterns for different cues. The results of the study showed a positive feedback from blind and VIP towards the proposed navigation assistance. From two alternate haptics actuator guiding methods, full blind subjects preferred one with two actuators, while partially blind/VIP preferred one using single actuator. It is evident that blind and VIP are positive about such assistance and both have different preferences. This fact can be utilized to make more tailored solution targeted as specific subset of this end user group.

7. FUTUE WORK

There are at least three areas which should be addressed in future work:

1. Conducting test with 5G network
2. Adding the second caretaker as a mentor in situations which are unfamiliar to the first caretaker who is a classical caretaker. In addition, more user tests are needed in the wider environment.
3. Automating and delegating part of assisting through artificial intelligence based support OR pre-recorded audio guidance
4. Moreover, there is a need to develop questionnaires especially designed for research with blind and VIP.

Acknowledgements: This study was funded by University of Oulu, UniOGS, Oulu University Scholarship Foundation and Oulu Advanced Research on Services and Information Systems OASIS research group. Warm thanks to the test participants.

8. REFERENCES

Aira. (n.d.) Web link retrieved 16th May 2020: htts://aira.io/

Arduino MKR 1010. (n.d.) Web link retrieved 31st May 2020: https://store.arduino.cc/arduino-mkr-wifi-1010

Avila, M., Wolf, K., Brock, A. and Henze, N. (2016), Remote assistance for blind users in daily life: A survey about be my eyes. In *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments*. ACM, 85.

Balata J., Mikovec Z., Maly I. (2015), Navigation Problems in Blind-to-Blind Pedestrians Tele-assistance Navigation. In: Abascal J., Barbosa S., Fetter M., Gross T., Palanque P., Winckler M. (eds) Human-Computer Interaction – INTERACT 2015. Lecture Notes in Computer Science, vol 9296. Springer, Cham

Baranski, P. and Strumillo, P. (2015), Field trials of a teleassistance system for the visually impaired. In *2015 8th International Conference on Human System Interaction (*HSI). IEEE, 173–179.

Be My Eyes. (n.d.) Web link retrieved 16th May 2020: htts://www.bemyeyes.com/

Benjamin JM Jr. (1974), The laser cane. *Bull Prosthet Res.* 1974;443-450. Samsung Galaxy 10

BeSpecular (n.d.) Web link retrieved 16th May 2020: https://www.bespecular.com/

Bradley, N.A. and Dunlop, M.D. (2005), An Experimental Investigation into Wayfinding Directions for Visually Impaired People. *Pers Ubiquit Comput* 9, 395–403 (2005). https://doi.org/10.1007/s00779-005-0350-y

Bujacz, M., Baranski, P., Moranski, M., Strumillo, P. and Materka, A. (2008), Remote guidance for the blind—A proposed teleassistance system and navigation trials. In 2008 Conference on Human System Interactions. IEEE, 888–892.

Blynk. (n.d.) Web link retrieved 31st May 2020: https://blynk.io

Clark-Carter, D., Heyes, A., Howarth, C. (1986), The efficiency and walking speed of visually impaired people. *Ergonomics* 29(6), 779–789 (1986)

Garaj, V., Jirawimut, R., Ptasinski, P. Cecelja, F. and Balachandran, W. (2003), A system for remote sighted guidance of visually impaired pedestrians. *British Journal of Visual Impairment* 21, 2 (2003), 55–63.

Golledge, R.G., Klatzky, R.L., Loomis, J.M. (1996), Cognitive mapping and wayfinding by adults without vision. In: Portugali, J. (ed.) The construction of cognitive maps, pp. 215–246. Springer, Dordrecht (1996)

Golledge, R.G. (1999), Human wayfinding and cognitive maps. In: Golledge, R.G. (ed.) Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes, pp. 5–45. *Johns Hopkins Press*, Baltimore (1999)

Helal, A., Moore, S. E., & Ramachandran, B. (2001), Drishti: An integrated navigation system for visually impaired and disabled. In *Proceedings fifth international symposium on wearable computers* (pp. 149-156). IEEE.

Høegh, R.T., Kjeldskov, J., Skov, M.B., Stage, J. (2008), A field laboratory for evaluating in situ. In: Lumsden, J. (ed.) *Handbook of Research on User Interface Design and Evaluation for Mobile Technology*, pp. 982–996. IGI Global, Hershey (2008)

Library of Congress. (n.d.) What is GPS? How does it Works? Library of congress website: https://www.loc.gov/everyday-mysteries/item/what-is-gps-how-does-it-work/. Retrieved on 14th of May 2020.

May, A.J., Ross, T., Bayer, S.H., Tarkiainen, M.J. (2003), Pedestrian navigation aids: information requirements and design implications. *Pers. Ubiquit. Comput*. 7(6), 331–338 (2003)

Maude D.R., Mark M.U., Smith R.W. (1983), AFB's Computerized Travel Aid: Two Years of Research. J. Vis. Impair. Blind. 1983;77:71, 74–75.

Millar, S. (1994), Understanding and Representing Space: Theory and Evidence from Studies with Blind and Sighted Children. *Oxford University/Clarendon Press*, Oxford (1994)

Millar, S. (2008), Space and sense. Psychology Press, New York (2008)

National Research Council. (1986), *Electronic Travel Aids: New Directions for Research*. Washington, DC: The National Academies Press. https://doi.org/10.17226/1011.

Petrie, H., Johnson, V., Strothotte, T. Raab, A. Michel, R., Reichert, L. and Schalt, A. (1997), MoBIC: An aid to increase the independent mobility of blind travellers. *British Journal of Visual Impairment* 15, 2 (1997), 63–66.

Ponchillia, P. E., Rak, E. C., Freeland, A. L., & LaGrow, S. J. (2007), Accessible GPS: Reorientation and target location among users with visual impairments. *Journal of Visual Impairment & Blindness*, 101(7), 389-401.

Raz, N., Striem, E., Pundak, G., Orlov, T., Zohary, E. (2007), Superior serial memory inthe blind: a case of cognitive compensatory adjustment. *Curr. Biol.* 17(13), 1129–1133 (2007)

Real, S., & Araujo, A. (2019). Navigation Systems for the Blind and Visually Impaired: Past Work, Challenges, and Open Problems. *Sensors*, 19(15), 3404.

Ross, T., May, A., Thompson, S. (2004), The use of landmarks in pedestrian navigation instructions and the effects of context. In: Brewster, S., Dunlop, M.D. (eds.) *Mobile HCI 2004.* LNCS, vol. 3160, pp. 300–304. Springer, Heidelberg (2004)

Rehrl, K., Häusler, E., Leitinger, S. (2010), Comparing the effectiveness of gps-enhanced voice guidance for pedestrians with metric- and landmark-based instruction sets. In: Fabrikant, S.I., Reichenbacher, T., van Kreveld, M., Schlieder, C. (eds.) *GIScience* 2010. LNCS, vol. 6292, pp. 189–203. Springer, Heidelberg (2010)

Samsung Galaxy 10. (n.d.) Web link retrieved 31st May 2020: https://www.samsung.com/us/mobile/galaxy-s10/

Siegel, A.W., White, S.H. (1975), The development of spatial representations of large-scale environments. *Adv. Child Dev. Behav*. 10, 9 (1975)

TapTapSee. (n.d.) Web link retrieved 16th May 2020: https://taptapseeapp.com/

Thinus-Blanc, C., Gaunet, F. (1997) Representation of space in blind persons: vision as a spatial sense? Psychol. Bull. 121(1), 20 (1997)

Huawei Honor 8. (n.d.) Web link retrieved 31st May 2020: https://www.gsmarena.com/honor_8-8195.php

Humanware. (n.d.), Trekker: "3.0 GPS orientation system." Solutions That Empower People With Vision Loss. Retrieved 4th December 2006: http://www.humanware.ca/web/en/Trekker3.asp

Tversky B. (1993), Cognitive Maps, Cognitive Collages, and Spatial Mental Models. Springer; Berlin/Heidelberg, Germany: 1993. pp. 14–24.

USAB. (n.d.) Web link retrieved 31st May 2020: https://www.usaba.org/membership/visual-classifications/

VizWiz. (n.d.) Web link retrieved 16th May 2020: http://iaccessibility.com/apps/low-vision/index.cgi/product?ID=65

White, R.W., Grant, P. (2009), Designing a visible city for visually impaired users. In: *Proceedings of the 2009 International Conference on Inclusive Design* (2009)

WHO (n.d.) Retrieved 20th May 2020 https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment (8 October 2019)

Williams, M. A., Hurst, A., & Kane, S. K. (2013, October). " Pray before you step out" describing personal and situational blind navigation behaviors. In Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (pp. 1-8).

Using Virtual Reality Applications for Management of Chronic Cancer Pain: User perceptions and preferences.

G Tao[1], T Taverner[2], E Cordingley[3], C Sun[4], B Garrett[5]

[1]Graduate Programs in Rehabilitation Science, The University of British Columbia, Vancouver, CANADA
[2]Canuck Place Children's Hospice, Vancouver, CANADA
[3,4,5]School of Nursing, The University of British Columbia, Vancouver, CANADA

[1]*gordon.tao@ubc.ca*, [2]*tarnia.taverner@canuckplace.org*, [3]*kewcordingly@ubc.ca,*
[4]*crystal.sun@ubc.ca,* [5]*bernie.garrett@ubc.ca*

EXTENDED ABSTRACT

1. INTRODUCTION

The management of chronic cancer pain remains challenging, involving both pharmacological and non-pharmacological approaches. Access to pain management clinics and resources remain limited by geography and socioeconomic factors (Kwon, 2014). Therefore, novel approaches to community-based patient self-management are required. Whilst virtual reality (VR) therapy has been shown to benefit acute pain (Garrett et al., 2014), its usefulness for chronic pain management remains unclear. VR technology immerses users in virtual environments to the effect of creating a sense of presence, thus serving as a mechanism for pain distraction (Li et al., 2011). Moreover, VR may support acceptance and adherence to mindfulness meditation for pain (Rosenzweig et al., 2010). This work explores how people living with and beyond cancer perceive VR experiences as an adjunctive therapy used at home.

2. METHODS

In an ongoing clinical trial (clinicaltrials.gov, NCT 02995434) involving cancer survivors, participants in the VR group used 4 VR activities at home for 4 weeks: 1 activity for 6 days, minimum 30 min per day. The custom developed applications Virtual Meditative Walk (MW) and Wildflowers (WF) were based on mindfulness meditation. The commercial videogames Carpe Lucem (CL) and Obduction (OB) were puzzle-oriented games used to support cognitive engagement and distraction from pain. Participants were provided with a PC and HTC Vive VR system. All activities were performed in seated position. Participants completed weekly surveys developed through literature review that included Likert scale items (strongly disagree, disagree, neutral, agree, strongly agree) to evaluate the perceived visual immersion (5 items), audio immersion (5 items), engagement (7 items), and sense of presence (7 items) experienced in each activity. A subsample of participants participated in two focus groups over teleconference to explore their experiences after their one-month VR intervention period.

Survey responses were summarized descriptively. Likert items were assigned numeric values and summed for total scores in each category. Themes developed from the focus groups using interpretive description analysis were used to evaluate associations of interest amongst survey results using Pearson correlation.

3. RESULTS

Overall, preliminary survey responses (n = 34) showed positive agreement (agree or strongly agree) in terms of visual immersion (63-88% of respondents) and audio immersion (62-80%) for each item across all activities. For engagement, 6/7 items showed positive agreement (53-70%); the remaining item showed 45% positive agreement. For presence, 5/7 items showed positive agreement (51-73%); the remaining items showed 37% and 30% positive agreement. Total Likert scores between activities showed CL as having the overall highest visual immersion (Figure 1). Across all categories, MW had the greatest variance in scores.

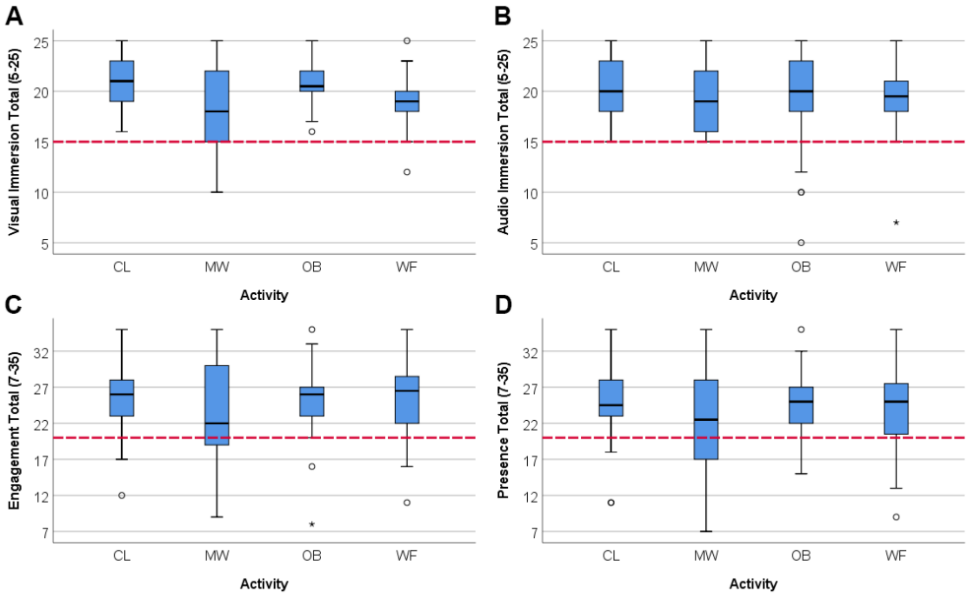


Figure 1. Bar charts of total Likert scale scores for (A) visual immersion, (B) audio immersion, (C) engagement, and (D) sense of presence. Red lines denote total for "neutral" on all items.

For experience of cybersickness over the 6 days, participants responded "neutral", "agree", or "strongly agree" at 12% for CL, 29% for MW, 35% for OB, and 56% for WF. From the focus groups 5 themes emerged reflecting personal activity preferences and frustrations, benefits and negative effects from each VR experience, usability considerations, mode of action (i.e. relaxation, distraction, immersion, and presence), and technical considerations. While most focus group participants said they experienced benefit from VR meditations, they appeared split between meditation vs cognitive engagement as their most preferred VR experiences. Therefore, we combined Likert score totals between meditative activities (MW + WF) and cognitive activities (CL + OB). Pearson correlation showed statistically significant association between meditative and cognitive activity scores for visual immersion ($r(31) = 0.53$, $p = 0.002$), audio immersion ($r(26) = 0.58$, $p = 0.002$), engagement ($r(25) = 0.61$, $p = 0.001$), and presence ($r(26) = 0.72$, $p < 0.001$).

4. CONCLUSION

Overall, the preliminary participant survey responses indicated the four VR applications used for adjunctive pain management were immersive, engaging, and produced a sense of presence. The commercial videogames CL and OB were perceived as more immersive than meditative applications. Unsurprisingly, WF, a flying activity, induced the most cybersickness. Yet, this did not appear to detract from its immersion, engagement, and presence compared to other activities. While focus groups highlighted individual preferences between meditative vs cognitive activities, these preferences were not reflected in survey responses, where higher ratings in cognitive activities were associated with higher ratings in meditative tasks, suggesting that individual preferences between cognitive and meditative activities are less dependent on VR qualities.

5. REFERENCES

Garrett, B, Taverner, T, Masinde, W, Gromala, D, Shaw, C, & Negraeff, M, (2014), A Rapid Evidence Assessment of Immersive Virtual Reality as an Adjunct Therapy in Acute Pain Management in Clinical Practice, *The Clinical Journal of Pain*, *30*(12), 1089–1098.

Kwon, JH, (2014), Overcoming Barriers in Cancer Pain Management, *Journal of Clinical Oncology*, *32*(16), 1727–1733.

Li, A, Montaño, Z, Chen, VJ, & Gold, JI, (2011), Virtual reality and pain management: Current trends and future directions, *Pain Management*, *1*(2), 147–157.

Rosenzweig, S, Greeson, JM, Reibel, DK, Green, JS, Jasser, SA, & Beasley, D, (2010), Mindfulness-based stress reduction for chronic pain conditions: Variation in treatment outcomes and role of home meditation practice, *Journal of Psychosomatic Research*, *68*(1), 29–36.

Intelligent virtual environment for treating anxiety exploring the Eye Movement Desensitization and Reprocessing technique

Bruna Cons[1], Fernando M. de Oliveira[2], Vera Maria B. Werneck[1], Rosa Maria E. Moreira da Costa[1]

[1]Programa de Pós-Graduação em Ciências Computacionais
Universidade do Estado do Rio de Janeiro - UERJ
Rio de Janeiro, RJ, BRAZIL

[2]Instituto Federal de Educação, Ciência e Tecnologia do Rio de Janeiro - Campus Arraial do Cabo
Rio de Janeiro, RJ, BRAZIL

brunacons@hotmail.com, *fmoinfo@gmail.com*, *vera@ime.uerj.br, rcosta@ime.uerj.br*

[1]*https://ccomp.ime.uerj.br/,* [2]*https://portal.ifrj.edu.br/arraial-do-cabo*

ABSTRACT

In the last years, the dissemination of Artificial Intelligence and Virtual Reality applied in the health area have expanded, opening new treatment possibilities for people with different disabilities. The integration of these technologies has been explored in some applications in the health area. On the other hand, the EMDR (Eye Movement Desensitization and Reprocessing) therapy is used to desensitize bad feelings and sensations associated with traumatic memories, exploring the rapid horizontal movement of the eyes. The purpose of this work is to integrate Artificial Intelligence techniques (Multi-agents and Fuzzy Logic) with immersive Virtual Reality technology to create a system capable of supporting the treatment of anxiety using the EMDR strategies to desensitize past traumatic events.

1. INTRODUCTION

Computer technologies, especially Artificial Intelligence (AI) and Virtual Reality (VR), applied in health have opened new possibilities for research and treatment of neuropsychiatric disabilities (Coffey, 2016). The benefits of using 3D virtual environments are pointed out in different applications with immersive exposure therapies, such as for phobias treatment (Botella, 2017) and Post-Traumatic Stress Disorder (Cárdenas-Lópes, 2014). Artificial Intelligence, exploring Multi-agent, Fuzzy Logic, and Machine Learning techniques, has been used to active guidance of physicians in their treatment decisions (Hamet, 2017) and clinical decision support systems (Castaneda, 2015), among others.

In the neuropsychiatric area, the Eye Movement Desensitization and Reprocessing (EMDR) is a therapy technique that considers that repetitive, horizontal eye movement, guided by therapeutic assistance, helps to reduce bad feelings associated with traumatic memories (Shapiro, 1989b). EMDR has been applied in the treatment of the desensitization of painful memories, reducing anxiety symptoms. This therapy has already been explored in some technological applications with a promising game application (Wang, 2018), Virtual Reality (Rousseau, 2019), and Artificial Intelligence (Graydanus,2018).

Supported by a Mapping Literature Review, this paper proposes a system that integrates Multi-agent, Fuzzy Logic, and Virtual Reality techniques to assist the EMDR technique for desensitizing past events.

The EM-VR system presents a virtual therapist who interacts with the user, collecting information about his traumatic memory and current anxiety level. The integration of these data in a Fuzzy system controls the level of stimuli intensity presented in the Virtual Reality environment to guide the exercise to be performed with the eyes. The use of Fuzzy Logic is ideal for this kind of evaluation, as it allows a weighting of diffuse values coming from the heartbeat combined with the answers about the patient's anxiety level. This information is obtained through a bot that explores dialogues with the patient using natural language.

The multi-agent architecture controls the entire flow of activities and data from the Fuzzy module, using this information to change the rhythm of eye movements presented to the patient. The use of Multi-agents provides autonomy in the modularization of system tasks. In this way, the system works independently of human intervention.

After this introduction, the paper presents five more sections. The second section presents the Eye Movement Desensitization and Reprocessing-EMDR theory. The third section describes the AI techniques. The Mapping Literature review is described in the fourth section and provides the software requirements. The fifth section presents the system that integrates AI, Fuzzy Logic, and immersive visualization. Section six concludes the paper and presents future perspectives.

2. EMDR

The psychologist Francine Shapiro was walking in a park when she observed that moving her eyes continuously, negative emotions related to the memories were softened. While including the eye movement in the cognitive therapy, a new psychotherapy procedure was created, called Eye Movement Desensitization and Reprocessing: EMDR.

Shapiro conducted a case study (Shapiro, 1989b) and a controlled study (Shapiro, 1989a) to test the efficacy of this technique. Twenty-two people with traumatic memories were treated, where half of them received the EMDR therapy and the other half received the same treatment, but without the eye movement. The studies concluded that the use of EMDR resulted in a significant decrease in the patients' angst and a representative increase in their self-confidence (EMDR Institute, 2020). The EMDR technique stimulates the two brain hemispheres, allowing both to work better together instead of the predomination of the sentimental area, which can cause feelings of distress and desperation while remembering traumatic memories.

The EMDR therapy is based on the eyes movement during the Rapid Eye Movement (REM) sleep phase. In this phase there's greater brain activity, when the most vivid dreams occur, increasing a person's humor, memory, and learning abilities. In a REM sleep phase, memories are processed, and digested by the brain, discarding neural connections linked to unwanted or uninteresting memories (Crick, 1995). Therefore, the use of a mechanical eye movement while the person is awake can help to process and digest memories that were not accessible over time.

The technique bases itself on a therapeutic approach called Adaptive Information Processing, which posits that traumatic memory is stored in the brain's neural network. EMDR allows bad feelings and beliefs associated with memory to be replaced by a more positive attitude from brain plasticity, which is the brain's ability to regenerate and create new connections between its neural networks through external stimuli (EMDR European Association, 2019). Stimulation of positive beliefs during the therapy session is expected to weaken neural networks connection associated with traumatic memory.

3. ARTIFICIAL INTELLIGENCE CONCEPTS

3.1. Fuzzy Logic

Unlike Boolean logic, which only admits Boolean values, such as 0 or 1, true or false, the Fuzzy Logic includes the values between 0 and 1. Fuzzy logic is used in systems that need a wide range of options, which makes it useful in complex problems that require a qualitative analysis and must cover a higher level of uncertainty in the results (Zadeh, 1965).

The use of fuzzy logic in psychotherapeutic systems is very consistent with the inherent uncertainty of human emotions and sensations, and that is why this technique was chosen to implement a calculation of the patient's probable level of anxiety. In this case, the Fuzzy Logic module will combine the user's heart rate with the users' answers to a SUDS (Subjective Units of Disturbance Scale) questionnaire that assesses the degree of anxiety during a stimulation session (Tanner, 2012). The SUDS scale with values between 0 and 10, measures the intensity of disturbance of someone exposed to stressful situations. According to Tanner (2012), in general, patients' ratings of their emotional discomfort were significantly higher than ratings of their physical discomfort. On the other side, Pole (2007) stresses that the heart rate level confirms or not the patient's anxiety level. Thus, the union of these two measures in a fuzzy logic module can minimize errors about the anxiety level of the user.

3.2. Multi-Agents

A Multi-Agent System (MAS) is a structure of coordinated autonomous entities that cooperate to achieve a common goal (Maes, 1995). It can have a collection of characteristics associated with autonomy and intelligence. In general, a Multi-Agent System is divided into modules that work in a coordinated way, with its tasks and objectives. Agents mostly communicate through the exchange of messages. There are many methodologies for modeling agents which are essential to determine the functionalities and the network of exchanging messages among them (Sturm, 2014).

4. MAPPING LITERATURE REVIEW

In general, systematic mapping is used to search for software evidence, according to Software Engineering standards (Petersen, 2015). For conducting the systematic mapping, a search protocol was elaborated containing: research questions, selection of publications, critical evaluation of papers, analysis, and presentation of results.

The purpose of this review is to obtain a broad view of a research area. In this sense, the research question is:

"How Artificial Intelligence has been currently used in Virtual Reality applications of the medical/health area?", and two secondary questions:

- Which Artificial Intelligence implementation techniques have been used in the medical/health area?
- What medical/health areas are being addressed?

The search was done in IEEExplore Digital Library, ACM Digital Library, PubMed, ICDVRAT, and ICVR websites. Only full papers which used some AI techniques and virtual reality were considered. The papers must be written in Portuguese or English, published between 2010 and 2018, and been available to be downloaded.

The English strings research used in the cited digital libraries were *("health" OR "medical" OR "dentistry" OR "physiotherapy") AND (virtual reality) AND ("multi-agent" OR "deep learning" OR "neural network" OR "machine learning" OR "fuzzy logic" OR "genetic algorithm" OR "ontology").* The same strings were translated into Portuguese to search for papers in that language.

When the inclusion criteria were not met, the papers were discarded. The review filtered 31 papers, which were summarized, analyzed, and compared. Figure 1a presents the results about the use of AI techniques. Figure 1b shows the predominant application area of the applications studied in this mapping.

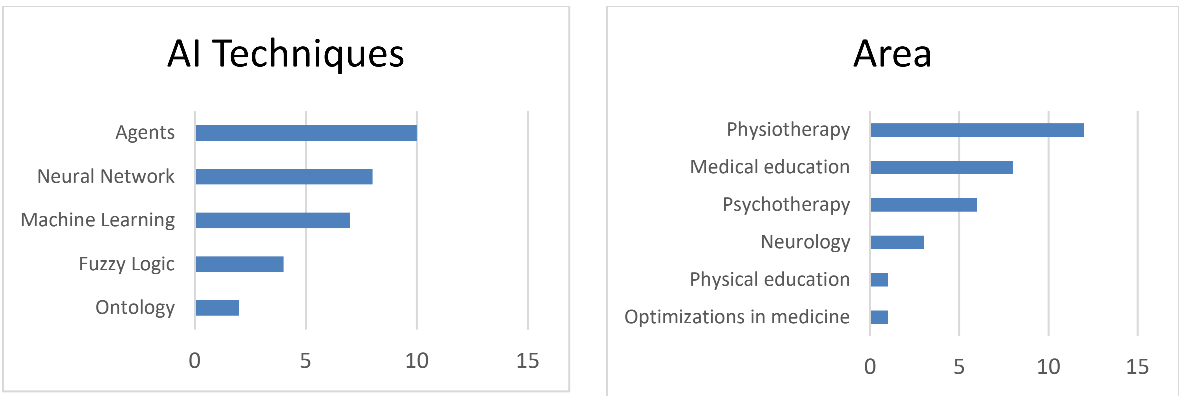


Figure 1a – Graph indicating the AI techniques; and Figure 1b – Graph indicating the areas of application reported in the papers

In the analysis of the results, we observed that most of the works applied in psychotherapy explored the multiagent techniques to control the interactions of the software with the patient. Also, we observed that the area of neurology usually adopts a multiagent structure. It seems to be a trend in applications that need to monitor the evolution of patient performance. Instead, areas that require less control over the stimulus levels evolution, such as physiotherapy, the technique of neural networks are the most adopted.

This study showed that 3D scenes can be useful in the health area, because, among other possibilities, it can make therapeutic sessions more pleasant and fun (Yeh, 2014); it can bring larger accuracy to laparoscopic surgeries, with the use of training systems for surgeons (Ahmad, 2013) and it increases a doctor's preciseness to a medical diagnosis (Lima, 2016). According to Rizzo (2016), VR simulation technology offers possibilities to create treatment environments that explore complex and immersive 3D scenarios, which control the level of stimuli generated from tracking user behavior and enables engagement in psychotherapy.

Although the selected works have 3D projections, few researchers explore immersive equipment (Carvalho, 2017), (Zhang, 2017). Some use haptic force devices (Xiong, 2012), mobile equipment for the 3D projection (Lydakis, 2017), and one integrates a device for heart rate detection (Wang, 2018).

This literature mapping provided elements for the software requirements to be defined, considering functionalities, platform, technologies, interface, and devices, which are presented in the following section.

5. EM-VR

EM-VR integrates MAS technologies with VR and the system performs a virtual therapy using a character as a therapist, which communicates with the patient in a male voice and receives input through an area text field.

Firstly, the character asks for the identification of the patient from the database. If the patient has already registered, the script will ensure that the users' information will be registered for further analysis by the therapist. If not, a new register will be created, and the patient will be introduced to EMDR system. The system is preferably used with the support of a therapist, who receives the patient's heart rate via communication with a digital clock and inserts it into the program when requested in the session. The therapist also supervises whether the patient is answering the questions of the system regarding their level of anxiety.

The system was built to reproduce the eight phases of the EMDR's, which are (Short, 2015; EMDR INSTITUTE, 2020): (i) Making sure the patient reflects about his traumatic memory, and what he thinks can be the origin of the problem. (ii) Explaining how the EMDR works. (iii) Creating a mental image of the traumatic memory, creating a negative belief, a future desired positive belief, and current emotions and sensations. The therapist asks for the patient to score their level of intensity in his emotions. (iv) The therapist asks for the patient to focus on the mental image of his traumatic memory and the body sensations provoked by it. Then, the therapist moves his finger in a left-right movement while the patient follows with the eyes. (v) The therapist instructs the patient to remember his positive belief, established at the beginning of the session. In the program, this phrase is shown on the screen. (vi) The therapist asks the patient to scan his body to identify residual physical discomfort. (vii) The therapist instructs the patient on a technique to relax and stabilize the emotions. In the system, cardiac coherence is used. (viii) The patient analyses his last thoughts and feelings that came up since the last session.

5.1 Agents

The system uses agents to give more autonomy to its tasks, either to display the character's scene, to receive and control the patient's information, to calculate his real anxiety level using fuzzy logic and use this information to modify the progress of the therapy session, through a control of the session script. The proposed agents are Scenography Agent, Analyzer Agent and Controller Agent.

The Scenography Agent generates and maintains the scene in the VR environment, exhibiting the living room with the therapist and the moving ball used by the Controller Agent. This agent ensures that the system will follow the order of an EMDR session, ending or pausing if necessary, controlling the session progress.

The Analyzer Agent is responsible for receiving the user's heart rate information and answers about his anxiety level, calculating the patient's real level of anxiety (low, medium, or high) using fuzzy logic, and sending this result to the Scenography Agent.

The Controller Agent receives the answers from the patients in the session, including the SUDs and the heart rate values. This agent maintains, controls, and sends the patient's information to the Fuzzy module for an afterward calculation of the patient's level of anxiety, via EMVR which is the entity that represents the software. It also stores the history of the therapy session.

5.2 I Modelling*

The EM-VR modeling used an objective-oriented structure, called i* (i-star) (Yu, 2011), considering the group's previous experience in using this structure and the dissemination of i* for modeling multi-agent systems. The i* framework provides the Strategic Dependency Diagram (SD) that identifies the actors (users and agents), the tasks, and the resources needed to process the tasks. The SD defines the network dependencies among the actors.

It supports the identification of agents, users, and their relationships. For example, the Controller depends on the EMVR agent to provide the Patient History and the Heart rate. On the other hand, the EMVR depends on the Controller to provide Monitoring of the patient interaction. Figure 2 shows the SD diagram, defining the relationship dependencies among the actors.

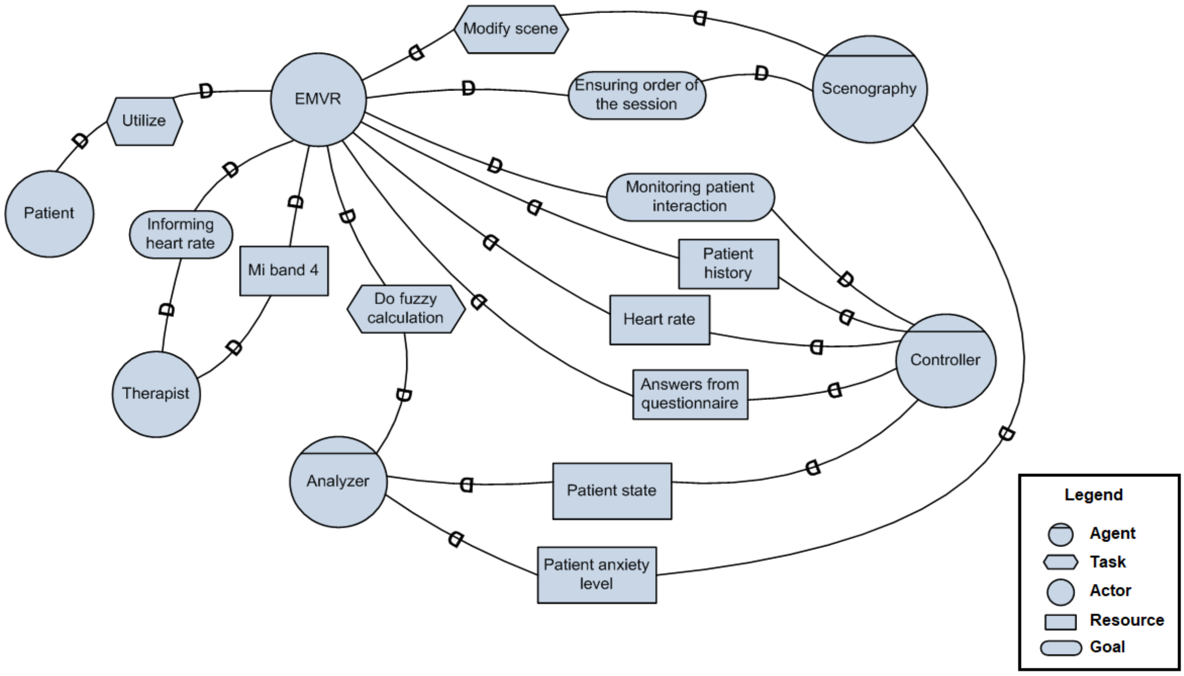


Figure 2. *EM-VR Strategic Dependency Model*

5.3 Fuzzy Logic

Phases iii and iv of the EMDR verify that the desired processing occurs. Two metrics were used to ensure that the patient is well enough to continue with the session:

i. The patient informs in a Subjective Unit of Distress Scale (SUDS), on a scale from 0 to 10, how high is his level of intensity of emotions.

ii. The system utilizes the Mi Band 4 device to measure the patient's heart rate. A window of tolerance was defined, where 60 bpm is considered a minimum value, and 85 is a maximum value. If the patient leaves the tolerance window, he will be instructed to perform the cardiac coherence exercise.

Both values (i and ii) are considered in a fuzzy logic module, which helps define how well the patient is. Figures 3a and 3b exhibit the functions of the fuzzy logic module.

The values of these fuzzy sets were defined by a cognitive-behavioral therapist expert in EMDR that generated twelve fuzzy rules to define the patient's calculated anxiety level. The inference table (Table 1) summarizes these fuzzy rules, with twelve different scenarios.

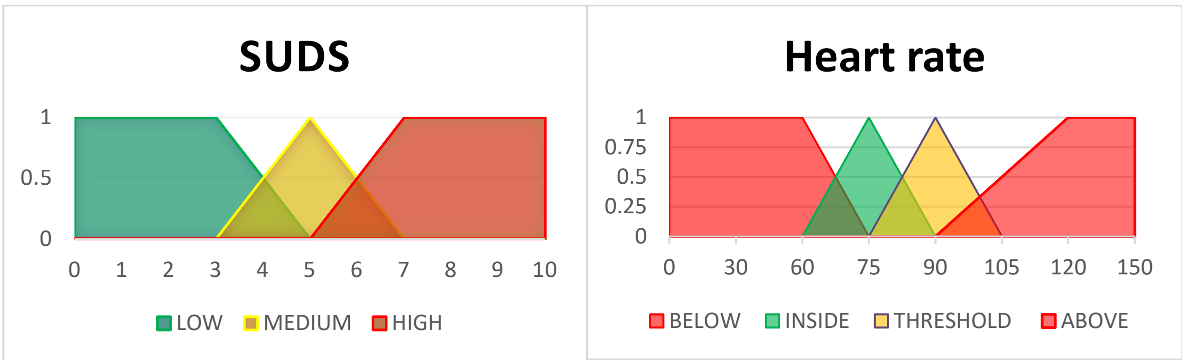


Figure 3a. *A fuzzy set for the patient's SUDS*; and **Figure 3b.** *A fuzzy set for the calculation of the patient's heart rate position in the defined window of tolerance*

Table 1. *Fuzzy inference table*

		Window of Tolerance			
		BELOW	INSIDE	THRESHOLD	ABOVE
SUDS	LOW	Medium	Low	Medium	High
	MEDIUM	Medium	Low	Medium	High
	HIGH	High	Medium	High	High

If the patient's calculated anxiety level is considered "Low", the procedures from the eight phases of the EMDR will occur normally, continuing with the visual stimulus of the ball movement to the patient's rapid eye movement. However, if the patient's anxiety is considered "Medium" or "High", the cardiac coherence exercise will be performed to calm the patient, and a new anxiety level will be calculated. The patient can only continue or leave the session if his anxiety level is low again. If the value reached "High" at any time during the session, as soon as the patient calms down, he will be able to choose to end the session or to continue.

5.4 Implementation

EM-VR was built using C# programming language in Visual Studio Code, and blueprints in Unity 3D. It was developed as a smartphone app. The idea is that every therapist can have this app on its smartphone, with the data of all their patients, including the patient's evolution over time. This is ensured by the system's SQLite database, which stores records of the patients' sessions. These records are saved in the Google Drive account linked to the smartphone in use; this means that all the patient's information's are saved at every end of a session.

In phase iv, the system replaced the therapist in the virtual system by a ball moving in the screen (Figure 4). Stages number iii and iv occur in a loop until the patient reports there is no more stress related to the memory, which is frequently asked by the EM-VR character. The final value of combining heart rate with anxiety level will generate a result that will control the speed of the ball in the scene, according to the EMDR protocols.

To use EM-VR, a few items would be necessary: (i) VR glasses or Smartphone with a gyroscope sensor; (ii) Mini USB keyboard for interaction with the virtual therapist (iii) Mi Band 4 bracelet, and (iv) Google Drive account, and consequently, Internet connection.

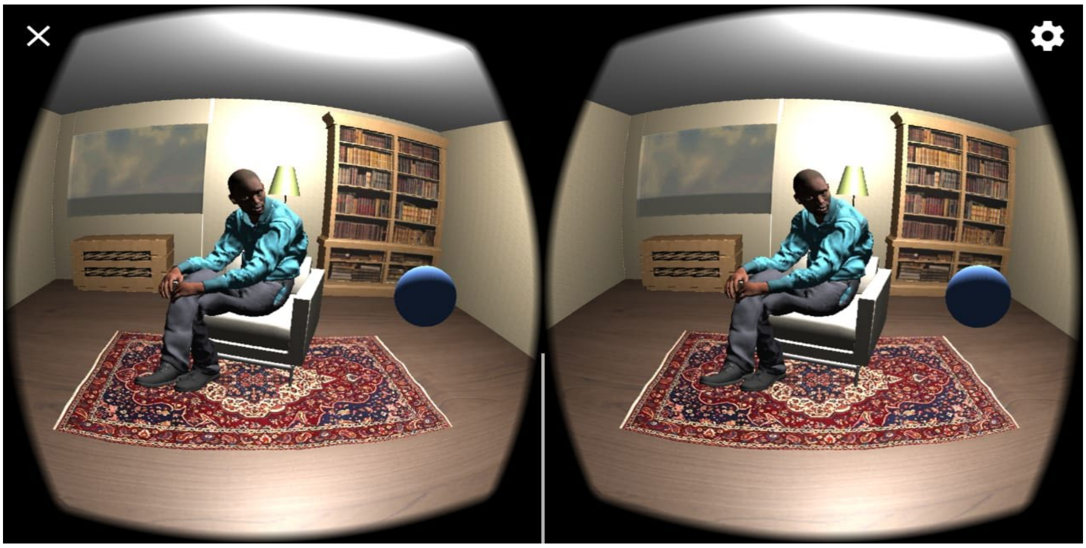


Figure 4. *Scene of the EM-VR showing the ball that moves in a stereoscopic visualization*

6. CONCLUSIONS

The mapping of the literature in anxiety treatment using EMDR identified that no studies were using 3D virtual environments with intelligent strategies to simulate EMDR. Therefore, the main objective of the project is to develop a system exploring current technologies, which make it possible to automate the treatment process.

The integration of Multi-agents with Fuzzy Logic allowed the creation of a system that generates a more motivating environment for the patient, since he can be very focused on performing the eyes movement, in a controlled environment, without receiving external stimuli. According to Yeh (2014), the virtual environments for neuropsychiatric treatments must be pleasant and fun.

We consider that the modeling of the agents allowed to identify their functionalities, and Fuzzy Logic allowed to make the classification of the level of anxiety more precise, since the heartbeat is considered very precise for the identification of the level of stress and the patient cannot lie about it.

In the first version, the system captured the patient's voice when he answered the SUD question about his anxiety level rating. However, the Unity software used to develop the 3D environment does not open many perspectives of integration with open specific tools for speech recognition, such as Google's Speech. Thus, we had to change this functionality so that the therapist would provide the value directly to the system. Another limitation of this study is the automatic capture of heartbeats. So far, the therapist receives this information automatically from the digital watch and is responsible for supplying the data to the system manually.

The project was submitted to the ethics committee and will be evaluated by a group of therapists. Further, the efficiency *of EM-VR* will be verified on sessions with patients and therapists to validate the system support of the anxiety treatment using the EMDR strategies.

REFERENCES

Ahmad, M et al., (2013) Benchmarking expert surgeons' path for evaluating a trainee surgeon's performance. 12th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and Its Applications in Industry. ACM, pp. 57-62.

Botella C, Fernandez-Alvarez, J, Guillén, V, García-Palacios, A, & Baños, (2017). Recent progress in virtual reality exposure therapy for phobias: a systematic review. Current psychiatry reports, **19**, 7, pp.42.

Braz, P, Werneck, VMB, Cunha, H, Costa, RMEM, (2018) SMEC-3D: A Multi-agent 3D Game to Cognitive Stimulation. In: Bajo J. et al.. (Org.). Communications in Computer and Information Science. 1ed.: Springer International Publishing, **887**, pp. 247-258.

Cárdenas-López, G., de la Rosa, A., Durón, R., & Durán, X. (2016). Virtual reality exposure for trauma and stress-related disorders for city violence crime victims. International Conference on Disability, Virtual Reality and associated Technologies- ICDVRAT, pp. 63-72.

Carvalho, S, et al. (2017) A Deep Learning Approach for Classification of Reaching Targets from EEG Images. Graphics, Patterns and Images-SIBGRAPI, IEEE, pp. 178-184.

Castaneda, C et al., (2015) Clinical decision support systems for improving diagnostic accuracy and achieving precision medicine. Journal of clinical bioinformatics, **5**, 1, pp. 4, 2015.

Coffey, MJ, Coffey, CE, (2016) The emerging story of emerging technologies in neuropsychiatry. Dialogues in clinical neuroscience, **18**, 2, pp. 127-134.

Crick, M, (1995) REM sleep and neural nets. Behavioural brain research, **69**, 1, pp. 147-155.

EMDR EUROPEAN ASSOCIATION. The AIP Model. Available in: <https://emdr-europe.org/about/the-aip-model/>. Accessed on 20 de abr. 2020.

EMDR INSTITUTE. Eye Movement Desensitization and Reprocessing Therapy. Available in: <https://www.emdr.com/>. Accessed on 20 de abr. 2020.

Greydanus, DE. et al. (2018) Children, youth, motor vehicle crashes, and post-traumatic stress disorder: Future research development. International Journal of Child and Adolescent Health, **11**, 2, pp. 247-251.

Hamet, P, Tremblay, J. (2017). Artificial intelligence in medicine. Metabolism, **69**, S36-S40.

Lima, R et al., (2016) A 3D serious game for medical students training in clinical cases. 2016 IEEE International Conference on Serious Games and Applications for Health (SeGAH). IEEE, pp. 1-9.

Lydakis, A, et al.. (2017), A learning-based agent for home neurorehabilitation. Rehabilitation Robotics (ICORR), International Conference on. IEEE, pp. 1233-1238.

Maes, P, (1995) Artificial Life Meets Entertainment: Lifelike Autonomous Agents. Communications of the ACM, **38**, 11, pp. 108-114.

Petersen, K, Vakkalanka, S, Kuzniarz, L, (2015), Guidelines for conducting systematic mapping studies in software engineering: An update. Information and Software Technology, **64**, pp. 1-18.

Pole, N, (2007), The Psychophysiology of Posttraumatic Stress Disorder: A Meta-Analysis. Psychological Bulletin, **133**, 5, pp. 725–746.

Rousseau, P F. et al., (2019), Increase of praecuneus metabolism correlates with reduction of PTSD symptoms after EMDR therapy in military veterans: an 18F-FDG PET study during virtual reality exposure to war. European journal of nuclear medicine and molecular imaging, **46,** 9, pp. 1817-1821.

Rizzo, A. et al., (2016) Clinical interviewing by a virtual human agent with automatic behavior analysis. International Conference on Disability, Virtual Reality and associated Technologies – ICDVRAT, pp. 57-64.

Shapiro, F,, (1989a), Efficacy of the eye movement desensitization procedure in the treatment of traumatic memories. Journal of traumatic stress, **2**, 2, pp. 199-223.

Shapiro, F, (1989b), Eye movement desensitization: A new treatment for post-traumatic stress disorder. Journal of behavior therapy and experimental psychiatry, **20**, 3, pp. 211-217.

Short, D, Leggett, ES, Bacon, K, (2015), Erickson- Derived or -Influenced Theories, *The SAGE Encyclopedia of Theory in Counseling and Psychotherapy*, Ed. Edward S. Neukrug. California.

Sturm, A, Shehory, O, (2014). The landscape of agent-oriented methodologies. In *Agent-Oriented Software Engineering*, pp. 137-154. Springer Berlin Heidelberg.

Tanner, B, (2012), Validity of global physical and emotional SUDS. Applied psychophysiology and biofeedback, **37**, 1, pp. 31-34.

Yeh, S-C et al., (2014), Machine learning-based assessment tool for imbalance and vestibular dysfunction with virtual reality rehabilitation system. Computer methods and programs in biomedicine, **116**, 3, pp. 311-318.

Yu E, (2011), Modeling Strategic Relationships for Process Reengineering, In: *Social Modeling Engineering*, editors. Yu E, Giorgini P, Maiden N, Milopoulos, J, Toronto, pp. 11-154.

Wang, C; Yu, G, (2018), Investigating the relationship between eye movement and brain wave activity using video games: pilot study. JMIR serious games, **6**, 3, pp. e16.

Xiong, A et al. (2012), Feasibility of EMG-based ANN controller for a real-time virtual reality simulation. In: IECON 2012-38th Annual Conference on IEEE Industrial Electronics Society. pp. 2699-2704.

Zadeh, L, (1965) A. Fuzzy sets. Information and control, **8**, 3, pp. 338-353.

Zhang, M, et al., (2017), Preliminary Application of Gesture Recognition to Virtual Acupuncture. In: Computational Intelligence and Design (ISCID), 10th International Symposium on IEEE, pp. 366-369.

Using virtual reality to improve classroom engagement in people with Down syndrome

S C Michalski[1*], A Szpak[1], C Ellison[1], R Cornish[2], T Loetscher[1]

[1]UniSA Justice & Society, University of South Australia,
Adelaide, South Australia, Australia

[2]Orana Australia Ltd.,
Adelaide, South Australia, Australia

[*]stefan.michalski@mymail.unisa.edu.au

ABSTRACT

People with Down syndrome experience various learning challenges. Introducing new and enjoyable activities in learning settings may improve behaviour and engagement. Virtual reality (VR) can be used to deliver various experiences that may complement classroom teachings. This study aimed to investigate the feasibility of VR exposure for people with Down syndrome in learning settings. Observational data in the classroom was collected following two brief experiences: VR drawing and conventional drawing. Irrespective of the intervention, VR and conventional drawing significantly improved subsequent mood, attention, and overall behaviour in the learning setting. This study's results are promising as VR was found to be highly feasible in this sample.

1. INTRODUCTION

Down syndrome is a cause of intellectual disability that can provide challenges to individuals in learning settings (Wishart, 2001). Inattentiveness and withdrawal can be signs of distress and stereotypical behaviours in learning settings for people with Down syndrome (Shalev et al., 2019). Virtual reality (VR) holds great potential to deliver enjoyable experiences (Alex et al., 2021). Exposure to virtual environments that provide a sense of distance from routine may reduce stress and improve mood (Anderson et al., 2017). Thus, VR may be a unique way to improve behaviour and engagement in learning settings.

Using immersive technology in VR-inexperienced groups needs to be carefully introduced and monitored for possible negative experiences specific to that population. People with Down syndrome have structural eye abnormalities which may diminish their vision even when corrected (Krinsky-McHale et al., 2014). There is a high prevalence of near vision impairments in people with Down syndrome, and many have strabismus, which will affect their visual perception when using stereoscopic displays. A convergence insufficiency (inability to maintain binocular function) may lead to difficulty seeing depth in VR, increasing the likelihood of adverse VR experiences (Boon et al., 2020; Turnbull & Phillips, 2017).

Although there may be benefits to using VR, many people with Down syndrome have vision impairments which may lead to cybersickness. Hence, we conducted a feasibility study to investigate VR exposure for people with Down syndrome.

2. METHOD

Sixteen people with Down syndrome participated in the study. Participants completed two interventions: VR drawing and conventional drawing. Tilt Brush (developed by Google) was the application used to deliver the VR experience. Participants were provided blank A4 paper and their favourite colour pencil for the conventional drawing condition. The tasks were similar in that drawings were completed on a plain and neutral background, they used their favourite colour throughout, and the researcher indicated in both tasks that they had free time to draw for a maximum of ten minutes. After completing each activity, participants were asked if they felt dizzy or sick, then they returned to class.

Observational data was collected. Blinded staff members observed participants and provided ratings for changes in six categories: mood, attention, activity, impulses, anxiety, and withdrawal. As staff were blinded, they did not know which activity the participant completed (VR or conventional). Fifteen minutes after returning to the classroom, two staff rated changes in behaviour on a seven-point scale ranging from better (+3) to worse (-3). Zero represented no change. The raters scores were averaged. Subscales and the total score (sum) were analysed.

3. RESULTS & DISCUSSION

Large positive effects were found for both VR drawing and conventional drawing to improve subsequent behaviour in the learning setting. A series of one-sample t-tests were conducted to assess whether the interventions changed behaviour from zero (no change). One samples t-tests revealed that mood, attention, and overall scores were significantly different from zero after both VR and conventional drawing interventions. The effect sizes were large following the VR intervention and larger in comparison to conventional drawing. For the remaining variables, non-significant differences were found. A series of paired samples t-tests revealed no significant differences between VR drawing and conventional drawing on all the staff's ratings.

VR was tolerated well. Two participants (12%) asked to end the VR experience early, and five (31%) reported visual discomfort symptoms, including eye strain and dizziness. We were unable to quantify the severity of their symptoms as participants verbal abilities were somewhat limited. Therefore, behavioural observations were essential to detect if participants appeared distressed. No staff reported significant concerns following VR exposure. Furthermore, behaviour in the learning setting improved. If many participants were sick, we would expect to see a negative impact on behaviour. However, we found the opposite. The improved behavioural ratings and lack of distress identified in behavioural observations indicate minimal cybersickness in this study.

Learning-setting behaviour improved after both VR drawing and conventional drawing as assessed by blinded staff members. A brief drawing intervention was able to improve learning-setting behaviour significantly. However, there was no evidence that one intervention was more effective than the other. This study's results are encouraging for researchers and educators interested in using VR as participants enjoyed the experience and engaged in the task well. VR has excellent potential for people with Down syndrome, yet it is understudied. In this experiment, VR was used as a tool for leisure. In taking the next steps, researchers could investigate the potential for learning and training within immersive VR environments.

4. REFERENCES

Alex, M., Wünsche, B. C., & Lottridge, D. (2021). Virtual reality art-making for stroke rehabilitation: Field study and technology probe. *International Journal of Human-Computer Studies*, *145*, 102481. https://doi.org/10.1016/j.ijhcs.2020.102481

Anderson, A. P., Mayer, M. D., Fellows, A. M., Cowan, D. R., Hegel, M. T., & Buckey, J. C. (2017). Relaxation with immersive natural scenes presented using virtual reality. *Aerospace medicine and human performance*, *88*(6), 520-526. https://doi.org/10.3357/AMHP.4747.2017

Boon, M. Y., Asper, L. J., Chik, P., Alagiah, P., & Ryan, M. (2020). Treatment and compliance with virtual reality and anaglyph-based training programs for convergence insufficiency. *Clinical and experimental Optometry*, *103*(6), 870-876. https://doi.org/10.1111/cxo.13057

Krinsky-McHale, S. J., Silverman, W., Gordon, J., Devenny, D. A., Oley, N., & Abramov, I. (2014). Vision Deficits in Adults with Down Syndrome. *Journal of Applied Research in Intellectual Disabilities*, *27*(3), 247-263. https://doi.org/10.1111/jar.12062

Shalev, N., Steele, A., Nobre, A. C., Karmiloff-Smith, A., Cornish, K., & Scerif, G. (2019). Dynamic sustained attention markers differentiate atypical development: The case of Williams syndrome and Down's syndrome. *Neuropsychologia*, *132*, 107148. https://doi.org/10.1016/j.neuropsychologia.2019.107148

Turnbull, P. R., & Phillips, J. R. (2017). Ocular effects of virtual reality headset wear in young adults. *Scientific reports*, *7*(1), 1-9. https://doi.org/10.1038/s41598-017-16320-6

Wishart, J. (2001). Motivation and learning styles in young children with Down syndrome. *Down syndrome Research and practice*, *7*(2), 47-51. https://doi.org/10.3104/reports.113

Lab to Rehab: Is virtual reality being adopted clinically for children?

W Farr[1, 2], S Glegg[3], I Male[1, 2], D Green[4,5,6]

[1]Research and Innovation, Sussex Community NHS Foundation Trust, Brighton, UNITED KINGDOM

[2] Brighton and Sussex Medical School, Brighton, UNITED KINGDOM

[3]University of British Columbia, Vancouver, CANADA

[4]Brunel University, London, UNITED KINGDOM

[5]Royal Free London NHS Foundation Trust, London, UNITED KINGDOM

[6]Jönkoping University, Jönkoping, SWEDEN

[1]*Will.Farr@nhs.net* [1]*www.sussexcommunity.nhs.uk*, [2]*www.bsms.ac.uk*

ABSTRACT

***Objective**:* Little is known about the extent to which virtual reality and active video games (VR/AVG) are integrated into clinical rehabilitation practice in the UK. The purpose of this study was to quantify current VR/AVG use and learning needs by paediatric physiotherapists (PTs) and occupational therapists (OTs), and to identify key barriers and facilitators of VR/AVG integration. Results are compared between UK and Canadian respondents to highlight similarities and differences.

***Design**:* Cross-Sectional Survey

Materials and Methods: An online survey gathered demographic and VR/AVG use data, and evaluated the factors influencing therapists' adoption of VR/AVG using the Assessing Determinants of Prospective Take-up of Virtual Reality (ADOPT-VR)-2 Instrument. This measure is a clinically validated tool used in Canada and the United States that employed a 10-point Likert scale with anchors on extremes, converted to percentages of agreement below. Recruitment in the UK undertaken through social media networks, the UK Chartered Society of Physiotherapists and the Royal College of Occupational Therapists Child Youth and Family Specialist Section.. Descriptive statistics, including frequency and mean scores, were used to analyse data. Comparisons between the UK and a previous Canadian study are discussed descriptively.

Results: Of the 73 (53 PTs, 20 OTs) UK survey respondents, the majority worked in community (60%) or acute (26%) paediatric settings. Only 11% of UK respondents (12% in Canada) reported current use VR/AVG with their patients, with previous experience reported as: none (32%), minimal (42%), average (8%), or high (10%). UK attitudes towards VR adoption were more positive (mean 74% agreement vs. 64%), with marginally greater perceived usefulness (69% vs. 63%) than in Canada. Canadian therapists saw VR as easier to use (57% vs. 36%) and viewed current evidence more positively (56% vs. 44%). Managers in both countries were perceived as having little or no influence on VR adoption, with UK ratings more pronounced (16% vs. 24%) and lack of clinical IT support another potential barrier to adoption (13% vs. 35%). Canadian therapists viewed their own locus of control with respect to clinical adoption as more positive (40% vs. UK 17%) and reported a greater personal ability to use VR/AVG technology (39% vs. 25%). The availability of treatment space was perceived as a greater barrier in Canada (62% vs. 45%) than the UK, as was the availability of protected time to learn systems (30% vs. 23%).

Conclusion: Differences in attitudes, perceived ease of use, self-efficacy, and locus of control between UK and Canadian therapists suggest that tailored supports are needed to facilitate VR/AVG adoption in each country. UK therapists viewed the quality of evidence for VR adoption more negatively than those in Canada. Therapists in both countries wanted protected time to familiarise themselves with systems and evidence. Managers and IT professionals in healthcare must increase support to ensure the effective adoption of VR/AVG into paediatric clinical practice. Future directions include repeat administration of the survey to a larger sample to increase confidence in the generalizability of findings, and the testing of interventions to target key barriers to adoption, in order to evaluate their effectiveness at supporting VR/AVG uptake.

***Keywords*:** Survey, UK, ADOPT-VR, paediatrics, clinical

1. INTRODUCTION

"[I]t always feels like children do not receive enough therapy. Potentially Active Video Gaming (AVG) [Virtual Reality (VR)] could address some therapeutic limitations as it is always available/on-demand…not requiring professional intervention (other than for initial set up and regular reviews). It could constitute a supplement to any therapy received by the child at any moment in time. The child could access it as part of available treatment/therapy, or as part of a tool kit."

A parent of a disabled child explaining benefits of AVG

Virtual reality (VR) and Active Video Gaming (AVG) systems use motion capture technology and computer-simulated environments to enhance therapy (Farr et al., 2017, 2019; Juras et al., 2018). AVG via commercial systems can be low-cost, accessible, and acceptable to families and children with physical disabilities such as Cerebral Palsy (CP) and wheelchair users such as those with Duchenne Muscular Dystrophy, in a wide range of contexts such as clinic, home or even school (Hammond et al., 2014; Poole et al., 2020). . AVG can enhance motivation, improve muscle function, assist general wellbeing, reduce sedentary behaviour, and support existing clinical practice (Hickman et al., 2017). Evidence indicates high levels of compliance, motivation, and overall engagement exists for game-based interventions (Bonnechère et al., 2014). A recent systematic review encompassing individuals with stroke, Parkinson's disease and CP (Juras et al., 2018) comparing AVG interventions with conventional or no rehabilitation, reported significantly better results for AVG.

However, even with all the positive research, technology adoption is slow (Farr et al., 2017). Surveys on patients across broad areas of use, including CP, show only 12% of therapists in Canada, 18% in Scotland and 31% in United States currently use AVG technology (Levac et al., 2017, 2019; Thomson et al., 2016). Yet 76% (Canada), 61% (Scotland) and 69% (United States) of therapists would employ AVG in rehabilitation if it was provided (Glegg & Levac, 2018). Further, AVG appears to be used well in general paediatric care in the US and Canada (29% of all use), alongside muscular-skeletal problems (20%) and neurological disorders (13%) totalling 60% of all use, and all of which affect children with CP, the commonest motor neurodisability in childhood (Farr et al., 2019; Levac et al., 2017). So why is there a lag between lab-based work, and take-up in clinical contexts? This survey aimed to uncover the current state of VR/AVG systems in clinical settings, by asking therapists about their attitudes, opinions, and self confidence in using systems. The study further compared data collected from UK therapists to Canadian therapists with data collected from an earlier survey.

2. METHOD

2.1 Ethics

The survey was cleared by the Health Research Authority (HRA) on 14/8/2019 (REC reference 19/HRA/4405). The survey was distributed using the online platform Survey Monkey and was open between 14/8/2019 and 14/12/2019.

2.2 Survey

The ADOPT-VR2 (Levac et al., 2017) consists of 54 Likert scale items assessing 11 theoretical predictors of behavioural intention to use VR/AVG based on an extended Theory of Planned Behaviour (Ajzen, 1985). Each item is evaluated on a 10-point scale with anchors on extreme values. Constructs are grouped into three composites for analytical purposes: (1) Attitude (A), (2) Social Norms, and (3) Perceived Behavioural Control. In this context, Attitude refers to an individual's affective evaluation about using VR/AVG. This composite includes the constructs of Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Compatibility (CO) of the technology with practice preferences. Social Norms (SN) refers to perceived social pressure from others in general to use VR/AVG, and includes constructs specific to three social groups: Peer Influence (PI), Superior Influence (SI), and Client Influence (CI). Perceived Behavioural Control (PBC) refers to the therapists' belief that they have access to the resources, opportunities and environment to enable them to use VR. The two unique underlying constructs for PBC are Self Efficacy (SE), and Facilitating Conditions and Barriers (FCB). This theoretical composite/construct structure allows for general or detailed analysis of the predictive influence of each composite or construct on adoption behaviour.

2.3 Study population

The study population for this project was any paediatric physiotherapist (PTs) or occupational therapist (OTs) in England with or without experience using VR. We targeted our recruitment through national or county associations, related organizations, and direct contact with members (in the case of the recruitment notice being shared via email and social media networks) who are able to read and answer questions in English.

An estimated 58,000 members belong to the Chartered Society of Physiotherapy, of which 28,000 are active physiotherapists, and 33,000 belonging to the Royal College of Occupational Therapists in the United Kingdom, of which 16,000 would be childrens' OTs. An accurate estimate of the number of therapists in the United Kingdom given is not exact as this data is not publically available. Recruitment methods may overlap with respect to reaching individuals. National colleges of OT and PT combined may contain 50,000+ therapists, with 84% of these based in England. This equates to 23,520 PTs and 13,382 OTs. The NHS spends approximately 5% of its budget on paediatrics equating to approximately 1176 paediatric physiotherapists and 669 occupational therapists working in paediatrics. With a 20% response rate over three months, and based on prior surveys of uptake (e.g. Farr et al., 2017), this would enable a targeted recruitment sample of 369 (235 PTs, 133 OTs).

The Canadian survey (Levac et al., 2017) undertaken previously used a convenience sample of OTs and PTs working in Canada and were recruited by circulating a web link and information about the open survey through e-mails, electronic newsletters, and blog, website, and social media posts coordinated via provincial/territorial professional associations and/or colleges. An estimated 5400 possible respondents in the Canadian survey yielded a response rate of 20% with 1071 respondents. Only a subset of this data - Paediatric therapists - were used in this comparative analysis.

2.4 Survey Distribution

The survey was constructed and distributed using Survey Monkey, a secure online survey tool. Recruitment was made with an initial cascade email to colleges of practice to ask them to distribute. The Royal College of Occupational Therapists CYPF special interest section distributed the survey via email to current members. Existing contacts such as professional practice leaders at health centres across the country were also approached, as were Clinical Research Networks (an amalgam of regional counties to promote research), and links were also promoted through social media sites such LinkedIn, Facebook and Twitter.

3. RESULTS

Seventy-three therapists (53 paediatric physiotherapists and 20 occupational therapists) completed the survey (see table 1). This result fell under the original targeted sample size. The average time spent completing the survey was 9 minutes 43 seconds. The majority of completions occurred during the first month of the survey (N=53, 71%).

3.1 Respondents

Therapist respondents (see figure 1) primarily worked in a community health environment (46, 60%), or acute setting (20, 26%). The majority of respondents (see table 1) were PTs with one-third having over 20 years clinical experience. Most were from South-East England or London (42%), and 51% possessed a Bachelor's degree, with 32% of total respondents also possessing a research Masters' degree.

All respondents reported treating paediatric clients, with some diversity in the upper and lower age range of this definition from 0 years of age to 25, taking into consideration the extension of the law in the UK surrounding Education Health Care Plans to 25 years as of 2014. 34% reported working in the age range of 0-19, 13% with 0-4 year olds, 9% 0-21, 6% with 0-16 year olds. The remainder (41%) reported serving clients from 1-25 years of age.

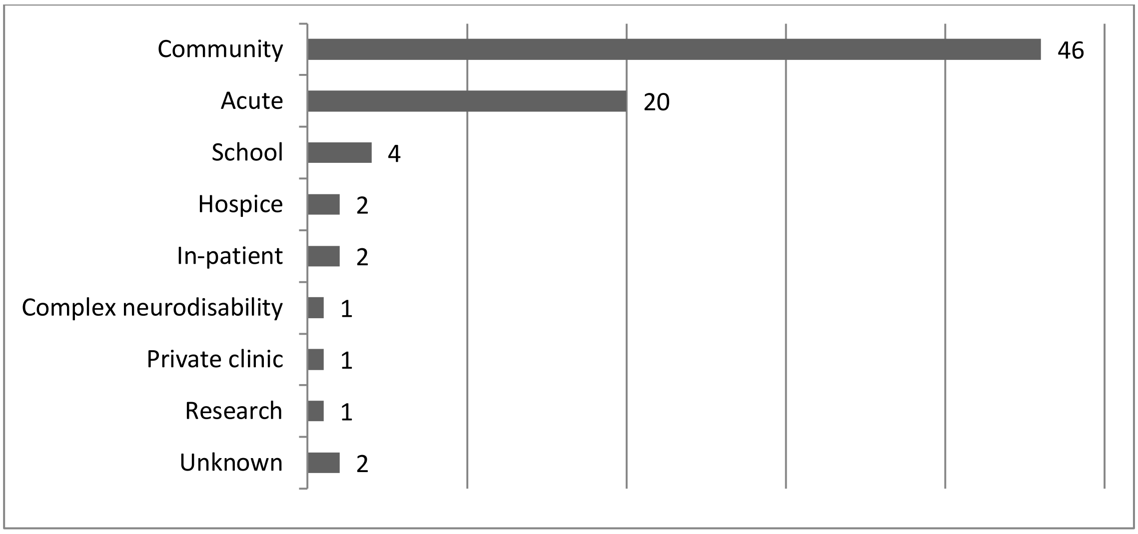


Figure 1. Most frequently reported practice settings of Virtual Reality/Active Video Gaming use in paediatrics

Table 1. *Participant Demographics (note: three respondents did not report their occupation)*

Participant Demographics	*Total sample* n = 73, n (%)	*OTs* n = 20, n (%)	*PTs* n=53, n (%)
Clinical experience			
<2 years	0 (0)	0 (0)	0 (0)
2-5 years	2 (3)	1 (1)	1 (1)
6-10 years	12 (15)	5 (6)	7 (9)
11-15 years	17 (22)	4 (5)	13 (16)
16-20 years	13 (16)	3 (4)	10 (13)
>20 years	32 (41)	7 (9)	25 (32)
No response	3 (4)		
Geographic region			
SE England	22 (28)	5 (6)	17 (22)
London	11 (14)	3 (4)	8 (10)
West Midlands	11 (14)	4 (5)	7 (9)
East of England	5 (6)	3 (4)	2 (3)
Yorkshire and the	11 (14)	5 (6)	6 (8)

Humber			
North West	2 (3)	1 (1)	1 (1)
South West	3 (4)	0 (0)	3 (4)
Wales	2 (3)	0 (0)	2 (3)
Scotland	1 (1)	0 (0)	1 (1)
Ireland	4 (5)	0 (0)	4 (5)
No response	2 (2)		
Level of education			
Diploma, Postgrad cert.	8 (10)	3 (4)	5 (6)
Bachelor Degree	40 (51)	10 (13)	30 (38)
Research masters	25 (32)	6 (8)	19 (24)
Doctoral degree	3 (4)	1 (1)	2 (3)
No response	3 (4)		

3.2 Survey Constructs

Table 2 below shows the construct scores for each of the three composites (Attitudes (A), Social Norms (SN) and Perceived Behavioural Control (PBC)). Scores are shown as percentages, with 100 a strong positive agreement with the survey item, and 0 strongly negative.

3.2.1 Attitudes toward VR. UK attitudes towards VR adoption were more positive (mean 74% agreement vs. 64%). However, overall composite attitudes, made up of A, PU, PEOU, CO, towards VR adoption were moderate with UK 56% agreement, and Canada 48%. Attitudes toward how compatible VR is with clinical practice were moderate in both countries (44% agreement).

Table 2. *Survey Composite and Construct Results*

Survey Construct	*UK % agreement (median)*	*Canadian % agreement (median)*
Composite Attitude (A, PU, PEOU, CO)	**56 (58)**	***48 (59)***
General Attitude (A)	74 (78)	*64 (67)*
Perceived Usefulness (PU)	69 (73)	*63 (67)*
Perceived Ease of Use (PEOU)	36 (35)	*57 (57)*
Compatibility (CO)	44 (46)	*44 (45)*
Composite Social Norms (SN, CI, PI, SI)	**29 (28)**	**33 (30)**
Social Norms (SN)	28 (27)	33 (30)
Client Influence (CI)	39 (47))	38 (30)
Peer Influence (PI)I	32 (21)	37 (35)
Social Influence (SI)	16 (10)	24 (20)
Composite Perceived Behavioural Control (PBC, SE,	**29 (24)**	**45 (44)**

FCB)		
Perceived Behavioural Control (PBC)	17 (11)	40 (38)
Self-Efficacy (SE)	25 (17)	39 (35)
Facilitating Conditions and Barriers (FCB)	45 (45)	51 (50)

3.2.2 VR/AVG Use. Only 11% of UK respondents (12% in Canada) reported currently using VR/AVG with their patients, 78% (62) reported no current use, with previous experience reported as: none (32%), minimal (42%), average (8%), or high (10%). Canadian therapists saw VR as easier to use (57% vs. 36%) with UK therapists reporting marginally more perceived usefulness (69% vs. 63%) than in Canada. Therapists rated their current experience of using VR/AVG as either none (N=25, 32%) minimal (17, 22%), beginner (16, 20%), average (6, 8%), good or high (8, 10%).

3.2.3 *Evidence and Implementation.* Canadian therapists viewed current evidence more positively (56% vs. 44%). 70% of UK therapists believe they do not currently have enough evidence for AVG/VR use. Over 56% of all therapists state that there is poor quality evidence to support use of VR. Managers in both countries were perceived as having little or no influence on VR adoption (SI), with UK ratings more pronounced (16% vs. 24%) and a lack of clinical IT support was viewed as another barrier to adoption (13% vs. 35%). The availability of treatment space was perceived as a greater barrier in Canada (62% vs. 45%) than the UK, as was the availability of protected time to learn systems (30% vs. 23%).

3.2.4 *Therapist Ability.* Canadian therapists viewed their own locus of control (PBC) with respect to clinical adoption as over twice as positive as therapists in the UK (40% vs. 17%) and reported greater personal ability to comparatively in their use VR/AVG technology (39% vs. 25%).

4. CONCLUSION

AVG has the continuing and growing potential to achieve therapeutic outcomes with reduced direct therapist input, and intervention effects seem to increase with the use of AVG interventions (Juras et al., 2018). Use of consistent and internationally agreed outcome measures of relevance to patients, with large enough sample sizes to inform reliable clinical adoption are persistent problems for research (Farr & Male, 2013; Hickman et al., 2017). Without consistent measures and samples sizes the impact on wider knowledge translation may contribute to slower adoption, impacting clinical take-up (Glegg & Levac, 2018). Furthermore, technology, is advancing at such a pace that it is difficult for researchers to complete the cycle of plan, pursue (funding), pilot, and plot results to confirm the efficacy of VR/AVG interventions, regardless of the device (Farr et al., 2019). Even then there are significant methodological issues to consider, for example in the use of appropriate placebo (Farr and Male, et al., 2017). Where bespoke systems are used, children complain that the quality of graphics and game play do not match commercially available systems, and whilst adults seem happy with this, for children it is a significant barrier to compliance with treatment (Farr et al., 2017)

VR/AVG is known to be motivational, yet the full implications of its motor learning impacts, as well as exploring prime conditions of implementation are unknown (Glegg & Levac, 2017; Lopes et al., 2018). In a UK setting, without good quality research evidence including large-scale, potentially multicentre RCTs, results are unlikely to feed into NICE guidelines and change practice. Whilst evidence is available to support VR/AVG as therapeutic adjuncts augmenting therapy benefits, therapists in both the UK and Canada remain reluctant to utilise opportunities. The reasons for the lack of uptake remain elusive but perhaps relate to how research results are disseminated and incremental cost-effective ratios are advertised.

Acknowledgements: Thanks go to co-authors Stephanie Glegg and Danielle Levac for allowing a UK team to use the ADOPT-VR survey and investigate national differences in VR adoption.

REFERENCES

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control: From Cognition to Behavior* (pp. 11–39). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-69746-3_2

Bonnechère, B., Jansen, B., Omelina, L., Degelaen, M., Wermenbol, V., Rooze, M., & Van Sint Jan, S. (2014). Can serious games be incorporated with conventional treatment of children with cerebral palsy? A review. *Research in Developmental Disabilities*, *35*(8), 1899–1913. https://doi.org/10.1016/j.ridd.2014.04.016

Farr, W. J., Green, D., Bremner, S., Male, I., Gage, H., Bailey, S., Speller, S., Colville, V., Jackson, M., Memon, A., & Morris, C. (2019). Feasibility of a randomised controlled trial to evaluate home-based virtual reality therapy in children with cerebral palsy. *Disability and Rehabilitation*, 1–13. https://doi.org/10.1080/09638288.2019.1618400

Farr, W. J., Poole, M., Thursfield, C., & Male, I. (2017). Acceptance of a Neuropaediatric Exergame Rehabilitation System with Severe Cerebral Palsy. *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play - CHI PLAY '17 Extended Abstracts*, 255–260. https://doi.org/10.1145/3130859.3131317

Farr, W., & Male, I. (2013). G216 A Meta-Analysis of "Wii Therapy" in Children with Cerebral Palsy. *Archives of Disease in Childhood*, *98*(Suppl 1), A97–A97.

Farr, William, Green, D., Male, I., Morris, C., Bailey, S., Gage, H., Speller, S., Colville, V., Jackson, M., Bremner, S., & Memon, A. (2017). Therapeutic potential and ownership of commercially available consoles in children with cerebral palsy. *British Journal of Occupational Therapy*, *80*(2), 108–116. https://doi.org/10.1177/0308022616678635

Farr, William, Male, I., Green, D., Morris, C., Gage, H., Bailey, S., Speller, S., Colville, V., Jackson, M., & Bremner, S. (2017). Methodological issues of using placebos in interventions based on digital technology. *Journal of Mobile Technology in Medicine*, *6*(2), 56–63.

Glegg, Stephanie Miranda Nadine, & Levac, D. E. (2018). Barriers, Facilitators and Interventions to Support Virtual Reality Implementation in Rehabilitation: A Scoping Review. *PM&R*, *10*(11), 1237-1251.e1. https://doi.org/10.1016/j.pmrj.2018.07.004

Glegg, Stephanie M.N., & Levac, D. E. (2017). Enhancing clinical implementation of virtual reality. *2017 International Conference on Virtual Rehabilitation (ICVR)*, 1–7. https://doi.org/10.1109/ICVR.2017.8007488

Hammond, J, Jones, V, Hill, EL, Green, D, & Male, I. (2014). An investigation of the impact of regular use of the Wii Fit to improve motor and psychosocial outcomes in children with movement difficulties: A pilot study. *Child Care Health Development*, *40*(2), 165–175.

Hickman, R., Popescu, L., Manzanares, R., Morris, B., Lee, S.-P., & Dufek, J. S. (2017). Use of active video gaming in children with neuromotor dysfunction: A systematic review. *Developmental Medicine & Child Neurology*, *59*(9), 903–911. https://doi.org/10.1111/dmcn.13464

Juras, G., Brachman, A., Michalska, J., Kamieniarz, A., Pawłowski, M., Hadamus, A., Białoszewski, D., Błaszczyk, J., & Słomka, K. J. (2018). Standards of Virtual Reality Application in Balance Training Programs in Clinical Practice: A Systematic Review. *Games for Health Journal*. https://doi.org/10.1089/g4h.2018.0034

Levac, D., Glegg, S., Colquhoun, H., Miller, P., & Noubary, F. (2017). Virtual Reality and Active Videogame-Based Practice, Learning Needs, and Preferences: A Cross-Canada Survey of Physical Therapists and Occupational Therapists. *Games for Health Journal*, *6*(4), 217–228. https://doi.org/10.1089/g4h.2016.0089

Levac, D., Glegg, S., Pradhan, S, Fox, E, Espy, D, Chicklis, E, & Deutsch, JE. (2019). *A comparison of virtual reality and active video game usage, attitudes and learning needs among therapists in Canada and the US.* International Conference on Virtual Rehabilitation (ICVR), Tel Aviv, Israel, July 21-24, 2019.

Lopes, S., Magalhães, P., Pereira, A., Martins, J., Magalhães, C., Chaleta, E., & Rosário, P. (2018). Games Used With Serious Purposes: A Systematic Review of Interventions in Patients With Cerebral Palsy. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.01712

Poole, M., Farr, W, Thursfield, C, & Male, I. (2020). Easy Access, Easy Use: Factors Influencing Active Video Gaming in Children who use Wheelchairs. *Proc.31st Annual Meeting of the European Academy of Childhood Disability, (EACD),*. European Academy of Childhood Disability, Poznan, Poland.

Thomson, K., Pollock, A., Bugge, C., & Brady, M. C. (2016). Commercial gaming devices for stroke upper limb rehabilitation: A survey of current practice. *Disability and Rehabilitation: Assistive Technology*, *11*(6), 454–461. https://doi.org/10.3109/17483107.2015.1005031

Effect of Immersive Visualization Technologies on Cognitive Load, Motivation, Usability, and Embodiment

N Wenk[1], J Penalver-Andres[1], K A Buetler[1], T Nef[2], R M Müri[2,3], L Marchal-Crespo[1]

[1] Motor Learning and Neurorehabilitation Laboratory, ARTORG Center for Biomedical Engineering Research, University of Bern, SWITZERLAND
[2] Gerontechnology & Rehabilitation, ARTORG Center for Biomedical Engineering Research, University of Bern, SWITZERLAND
[3] Department of Neurology, University Neurorehabilitation, University Hospital Bern (Inselspital), University of Bern, SWITZERLAND

[1]*nicolas.wenk@artorg.unibe.ch, ORCID: https://orcid.org/0000-0001-5425-0484*

[1]*www.artorg.unibe.ch/research/mln*

ABSTRACT

Patients with neurological dysfunction (e.g., after stroke) often suffer from motor and cognitive impairments. To regain (part) of their motor function, they must enroll in intensive neurorehabilitation programs. Virtual reality (VR) is a promising tool to enhance motivation and engagement of patients undergoing neurorehabilitation training. However, virtual training environments are usually displayed on computer screens, where patients interact via a virtual representation of their limb (e.g., an avatar) (Laver et al., 2017). While this provides useful visual guidance, it has several drawbacks. First, there is a loss of depth cues as the three-dimensional (3D) movements are displayed on a 2D screen (Gerig et al., 2018). Second, the visualization is shown in a different space from where the movements are performed, breaking eye-hand coordination. These visuospatial transformations may add cognitive load (Mousavi Hondori et al., 2016) to patients during training, reducing the VR usability, and, therefore, limit enrollment of cognitively impaired patients in VR therapy. Screens might further reduce rehabilitation outcomes if they limit patients' motivation and embodiment, factors previously associated with better motor performance (Grechuta et al., 2017; Maclean et al., 2000).

The implementation of commercially available low-cost head-mounted displays (HMDs) in neurorehabilitation is promising, as they allow patients to visualize their limbs' movements in real-time as avatars from a first-person perspective, reducing visuospatial transformation and preserving eye-hand coordination. No negative effects have been reported when HMDs were employed in elderly populations (Huygelier et al., 2019) and they raised enthusiasm in health specialists (Gobron et al., 2015). Further, it has been shown that real-time visualization of the patients' limb movements in a virtual environment with an avatar induces body ownership over the avatar's limbs (Borrego et al., 2019). Despite their potential, HMDs are seldom used in neurorehabilitation context.

The goal of this study was to evaluate the potential benefits of more immersive technologies using head-mounted displays (HMDs). We ran a within-subject experiment with 20 healthy young participants who performed simultaneously a 3D reaching (motor) task and a cognitive counting task using: i) Immersive VR (IVR) HMD, ii) Augmented reality (AR) HMD, and iii) Computer screen. The IVR and screen modality displayed the same VE from a first-person perspective and used a seated full-body humanoid avatar animated with inverse kinematics. In a previous analysis (Wenk et al., 2019), we reported improved motor performance when movements were visualized with IVR instead of the screen. Here, we present results from the analysis of questionnaires to evaluate whether visualization technology impacted cognitive load (using the well-established "Raw Task Load Index" (Hart, 2006)), motivation (using the subscales from the "Intrinsic Motivation Inventory" (Reynolds, 2007)), technology usability (using the "System Usability Scale" (Brooke,

1996)) and embodiment (using adapted questions from the "Rubber Hand Illusion" questionnaires (Kilteni et al., 2012; Longo et al., 2008)).

Reports on cognitive load did not differ across visualization technologies. However, IVR was more motivating and usable than AR and computer screen. Both, IVR and AR reached higher embodiment than the screen. Our results support our previous finding that IVR seems to be the most suitable visualization technology to train 3D movements in VR. For AR, it is still unknown whether the absence of benefit over the computer screen is due to the visualization technology per se or to technical limitations specific to the device.

REFERENCES

Borrego, A., Latorre, J., Alcañiz, M., Llorens, R., 2019. Embodiment and Presence in Virtual Reality After Stroke. A Comparative Study With Healthy Subjects. Front. Neurol. 10, 1061. https://doi.org/10.3389/fneur.2019.01061

Brooke, J., 1996. SUS: A "quick and dirty" usability scale, in: Jordan, P.W., Thomas, B., Weerdmeester, B.A., McClelland, I.L. (Eds.), Usability Evaluation in Industry. Taylor & Francis, London, pp. 189–194.

Gerig, N., Mayo, J., Baur, K., Wittmann, F., Riener, R., Wolf, P., 2018. Missing depth cues in virtual reality limit performance and quality of three dimensional reaching movements. PLOS ONE 13, 1–18. https://doi.org/10.1371/journal.pone.0189275

Gobron, S.C., Zannini, N., Wenk, N., Schmitt, C., Charrotton, Y., Fauquex, A., Lauria, M., Degache, F., Frischknecht, R., 2015. Serious Games for Rehabilitation Using Head-Mounted Display and Haptic Devices, in: De Paolis, L.T., Mongelli, A. (Eds.), Augmented and Virtual Reality. Springer International Publishing, Cham, pp. 199–219. https://doi.org/10.1007/978-3-319-22888-4_15

Grechuta, K., Guga, J., Maffei, G., Rubio Ballester, B., Verschure, P.F.M.J., 2017. Visuotactile integration modulates motor performance in a perceptual decision-making task. Sci Rep 7, 3333. https://doi.org/10.1038/s41598-017-03488-0

Hart, S.G., 2006. Nasa-Task Load Index (NASA-TLX); 20 Years Later. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 50, 904–908. https://doi.org/10.1177/154193120605000909

Huygelier, H., Schraepen, B., Ee, R. van, Abeele, V.V., Gillebert, C.R., 2019. Acceptance of immersive head-mounted virtual reality in older adults. Sci Rep 9, 1–12. https://doi.org/10.1038/s41598-019-41200-6

Kilteni, K., Groten, R., Slater, M., 2012. The Sense of Embodiment in Virtual Reality. Presence: Teleoperators and Virtual Environments 21, 373–387. https://doi.org/10.1162/PRES_a_00124

Laver, K., Lange, B., George, S., Deutsch, J., Saposnik, G., Crotty, M., 2017. Virtual reality for stroke rehabilitation (Review). Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD008349.pub4

Longo, M.R., Schüür, F., Kammers, M.P.M., Tsakiris, M., Haggard, P., 2008. What is embodiment? A psychometric approach. Cognition 107, 978–998. https://doi.org/10.1016/j.cognition.2007.12.004

Maclean, N., Pound, P., Wolfe, C., Rudd, A., 2000. Qualitative analysis of stroke patients' motivation for rehabilitation. BMJ 321, 1051–1054. https://doi.org/10.1136/bmj.321.7268.1051

Mousavi Hondori, H., Khademi, M., Dodakian, L., McKenzie, A., Lopes, C.V., Cramer, S.C., 2016. Choice of Human–Computer Interaction Mode in Stroke Rehabilitation. Neurorehabil Neural Repair 30, 258–265. https://doi.org/10.1177/1545968315593805

Reynolds, L., 2007. Measuring Intrinsic Motivations, in: Handbook of Research on Electronic Surveys and Measurements. IGI Global, pp. 170–173.

Wenk, N., Penalver-Andres, J., Palma, R., Buetler, K.A., Muri, R., Nef, T., Marchal-Crespo, L., 2019. Reaching in Several Realities: Motor and Cognitive Benefits of Different Visualization Technologies, in: 2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR). Presented at the 2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR), IEEE, Toronto, ON, Canada, pp. 1037–1042. https://doi.org/10.1109/ICORR.2019.8779366

Characterizing the Use of Interactive Technologies for Cognitive Rehabilitation in Portuguese Healthcare Institutions

Teresa Paulino[1] and Mónica S. Cameirão[2]

[1,2] Faculdade de Ciências Exatas e da Engenharia, Universidade da Madeira, Funchal, Portugal

[1,2] Madeira Interactive Technologies Institute, Funchal, Portugal

[1,2] NOVA Laboratory for Computer Science and Informatics (NOVA LINCS), Lisboa, Portugal

[1]*teresa.paulino@m-iti.org,* [2]*monica.cameirao@m-iti.org*

[1,2]*www.uma.pt,* [1,2]*www.m-iti.org,* [1,2]*nova-lincs.di.fct.unl.pt*

ABSTRACT

The increasing predominance of cognitive deficits following neurological conditions such as dementia and stroke is a major concern in Portugal. Cognitive rehabilitation has been shown to be fundamental to alleviate some of the deficits, but it is not always customized to the specific profile of each patient. More critically, patients typically do not have rehabilitation while they are in the waiting list or after discharge. One way to address these limitations is using interactive technologies specifically designed for cognitive rehabilitation. Their digital nature allows the customization of parameters enabling personalization and adaptation to each patient's profile, as well as the possibility of quantification of performance. In addition, these tools have the potential to be used at home, allowing patients to continue their rehabilitation and being monitored remotely, alleviating the burden of institutionalization for both patients and healthcare systems. However, before proposing novel technologies, it is imperative to understand current practices, needs, preferences and expectations of health professionals in this domain. For this purpose, we developed an online questionnaire that was distributed among health professionals in Portugal. 116 participants have responded, with 35% reporting having experience in the use of interactive technologies for cognitive rehabilitation. Our results show that health professionals that use these technologies mainly value ease of interaction, diversity of activities, task personalization to the patient's cognitive profile, and adaptation based on performance. These and other insights will be used to inform the development of novel tools for cognitive rehabilitation in clinical and home settings.

Keywords: Cognitive Rehabilitation, Interactive Technologies, Health Professionals, Survey, Human-Centered Design.

1. INTRODUCTION

The biological functional and cognitive decline of the elderly and associated risks (Carneiro et al., 2017) are determinant for dependent functioning in late life (Agüero-Torres et al., 2002). In Portugal, taking into account the expected increase in the ageing ratio, it is expected that the index of functionally dependent elderly will double from 33.9 in 2018 to 67.8 in 2080 for each 100 potentially active (INE, 2019). The aged population is also at a higher risk of suffering a stroke which can have an impact in cognitive function, and consequently on quality of life (Cumming et al., 2013).

Evidence shows that Cognitive Rehabilitation (CR) should target improving everyday functioning and result in meaningful outcomes valuable for the patients and their relatives (Cicerone et al., 2019). CR intervention strategies such as cognitive retraining, functional compensation, assessment, and goal setting and implementation are examples of common practices by Health Professionals (HPs) to achieve this goal (Nowell et al., 2019). However, several traditional CR practices rely on the use of games, puzzles, or paper and pencil activities that not always allow for customization according to each patient's cognitive profile, which is key for the success of rehabilitation (Pariente, 2006). Cognitive training and rehabilitation programs using Interactive Technologies (ITs) such as computer programs and technological devices are considered promising for improving cognitive function

(Ge et al., 2018). ITs have several advantages in comparison to traditional methods, for instance, technologies based on Virtual Environments (VEs) offer the possibility to simulate Activities of Daily Living (ADLs), allowing retraining everyday functioning while promoting enjoyment and adherence to CR (Maggio et al., 2019; Snoswell & Snoswell, 2019). The similarities of VEs to the real world provide the advantage of performing adapted tasks in safe and ecological environments (Ferche et al., 2015). Additionally, the digital nature of ITs allows the customization of parameters enabling personalization and adaptation to each patient profile along with the possibility of quantification of performance (Paravati et al., 2017). Several studies are showing promising results when using these technologies alone or in conjunction with traditional CR (Ge et al., 2018). For example, a recent study compared the effect of applying two types of ITs, a computerized cognitive training programme and a VE rehabilitation system (Baltaduonienė et al., 2019). The results showed that patients who underwent rehabilitation with ITs had their cognitive functions significantly improved compared with the group that only had occupational therapy sessions. Another study compared the performance of stroke patients that underwent adaptive cognitive training in a VE with those doing paper-and-pencil tasks (Faria et al., 2019). The results showed that both groups obtained similar performance, but the VE condition offered a more intensive training, a factor that can be relevant for recovery.

Despite the evidence that supports the effective usage of ITs for CR, not much is known about if and how they are being used in current CR interventions in Portuguese health institutions. For instance, there is not even any record in the Portuguese nomenclature of medical devices list that refers to CR system or software (SNS, 2020). Knowing how and to what extend these technologies are being currently used in daily practice as well as the main barriers for their adoption is crucial to inform the design of new ITs for CR that are more easily adopted and more effectively used. The current practices in CR and HPs' opinions and expectations towards the use of ITs have been studied in other countries such as the Netherlands (de Joode et al., 2012; Wentink et al., 2018), the United States (Wang et al., 2016), and Sweden (Gustavsson et al., 2020). The results from these studies provided useful information and recommendations towards the design and implementation of ITs for CR. For example, ITs for CR should promote the interaction between patients and HPs to share knowledge and experiences because the lack of information on ITs for CR is one of the most reported reasons for not using them (de Joode et al., 2012). Another example is that there should be an effort in creating some systematic delivery of training on how to use these technologies that can be easily accessed by patients and caregivers (Wang et al., 2016). However, these studies focussed on the use of assistive technologies to cognitive aid, and not so much on their use for cognitive training. Here, we investigate the current practices and HP' opinions towards the use of ITs, specifically for CR. For this purpose, we designed an online questionnaire that was disseminated to Portuguese healthcare institutions. Our target was to characterize six main domains: the profile of HPs, the healthcare institutions, the current practices in CR, the use of ITs in CR, rehabilitation at home with ITs, and the collaboration in the design of ITs for CR. Additionally, we also wanted to explore if there are differences in attitude towards using ITs for CR between HPs that are already using them and those who aren't. The results of this study will be used to inform the design of a CR platform for in situ and @home rehabilitation.

2. METHODS

2.1 Experimental Procedure

We developed an online questionnaire using Google forms to be self-administered by HPs currently practicing CR in Portuguese health institutions. The questionnaire was disseminated through different channels to reach the maximum number of HPs practicing CR in health institutions in Portugal. For this, an email was sent to various public and private Portuguese hospitals, rehabilitation centers, and non-profit healthcare institutions. Additionally, the questionnaire was also disseminated through social networks. Before dissemination, we performed an informal pilot with a psychologist experienced in the field, a team member representative of the target audience, to gather feedback on the content, length, and clarity of the questionnaire. After adjustments, the final version consisted of 9 main sections. Some items consisted on statements to be rated on a 6-items Likert scale (LS1-6), ranging from 1 = "I disagree completely" to 6 = "I agree completely". There were also open-ended questions and multiple-choice (MC) answers. At the beginning of the questionnaire, an informed consent was presented, and the participant could only proceed after agreeing. The sections of the questionnaire were grouped in different domains that included the following items:

2.1.1 *The Health Professional*

- *Section 1.* Participant demographics: age; gender; profession; field of specialization; schooling; year of highest degree; years of experience.

2.1.2 *The Healthcare Institution*

- *Section 2.* Health institution information: institution type; district; access to technological resources (LS1-6); amount of people working on Information and Communication Technologies (ICT) (LS1-6).

2.1.3 *Current Practices in CR*

- *Section 3.* Information about current practice in CR: patients' pathologies (MC); patients' age range (MC); session duration; intervention duration; activities performed (MC); usage of ITs in CR (yes/no);

2.1.4 *CR with ITs*

- *Section 4.* CR with ITs: ITs used (MC); context of usage; amount of ITs usage (LS1-6); patient's independence while performing activities through ITs (LS1-6); health professional intervention during the session (LS1-6); essentiality of ITs for CR success (LS1-6).
- *Section 5.* IT task personalization and adaptation: level of automation in terms of personalization (LS1-6); level of automation in terms of difficulty adaptation based on patient performance over time (LS1-6).
- *Section 7.* Level of importance of various characteristics when choosing ITs for CR (LS1-6).
- *Section 9.* Reasons for not using ITs in CR (MC).

2.1.5 *@Home CR with ITs*

- *Section 6.* CR at home with IT: prescription of ITs to be used at home (yes/no); preference for monitoring patients progress; level of independence of patients while performing CR through ITs at home (LS1-6).

2.1.6 *Collaboration in the design process*

- *Section 8.* Collaboration in the design process of ITs for CR: participation in the design process (yes/no/I don't know); preferred types of participation (MC); level of importance of different entities on the design process (LS1-6).

2.2 *Data Analysis*

Data are presented as frequencies and percentages for categorical variables. Median and interquartile range, Mdn (IQR), are used as central tendency and dispersion metrics for ordinal variables. Mean and standard deviation (STD) are used for interval type measures. The Mann-Whitney test was used to test for two-sample between-group differences in ordinal variables. When testing for significance, the threshold was set at 0.05. Data were analysed using IBM SPSS Statistics 26.

3. RESULTS

We have collected data from 116 participants. We organized the results in 6 major domains: profile of HPs, healthcare institutions, current practice in CR, use of ITs in CR, @home CR with ITs, and collaboration in the design of ITs for CR.

3.1 *What is the profile of HPs conducting CR in Portugal?*

The respondents were mostly female (N=93, 80.2%). Most respondents were in the 36-45 (N=48, 41.4%) or in the 26-35 (N=39, 33.6%) age range. 65.5% of the participants had more than 10 years of experience (N=76). 41 were nurses (35.3%), 40 therapists (34.5%), 30 psychologists (25.9%), and 5 clinicians (4.3%). Most reported fields of specialization were occupational therapy (N=27, 23.5%), generic clinical (N=24, 20.9%), and physical and rehabilitation care (N=22, 19.1%).

3.2 *What type of healthcare institutions have been reported?*

The most represented institutions were public (N=65, 56%), followed by private (N=29, 25%), non-profit (N=17, 14.7%) and mixed (N=5, 4.3%). Lisbon (N=23) and Porto (N=20) were the districts with higher number of respondents. Concerning the access level to technology of the institution, on the statements “The institution has a high level of access to technological/digital resources” and “The institution has a high level of access to human resources working in ICT”, the median ratings were Mdn = 3 (2) and Mdn = 2 (2), respectively.

3.3 *What are the current practices in CR?*

- *End-users.* Patients with dementia (N=90, 77.6%), stroke (N=72, 62.1%), and Parkinson’s disease (N=44, 37.9%), with more than 60 years (N=99, 85.3%) are the main clients of CR (Figure 1).

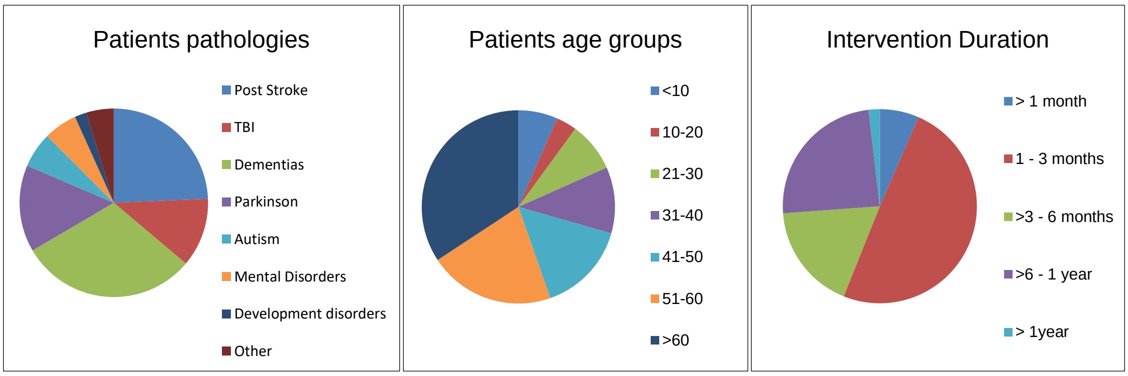


Figure 1. Pie charts of patients' pathologies (left), patients’ age groups (middle) and duration of CR interventions (right).

- *Duration.* A CR session lasts in average 38 min (SD = 13). Respondents reported that CR programs typically last 1 to 3 months (N=53, 49.35%) or longer (Figure 1).
- *Activities.* The most common activities currently used are puzzles and games (N=92, 79.3%), paper and pencil tasks (N=89, 76.7%), and training of Activities of Daily Living (ADL) (N= 89, 76.7%) (Figure 2).

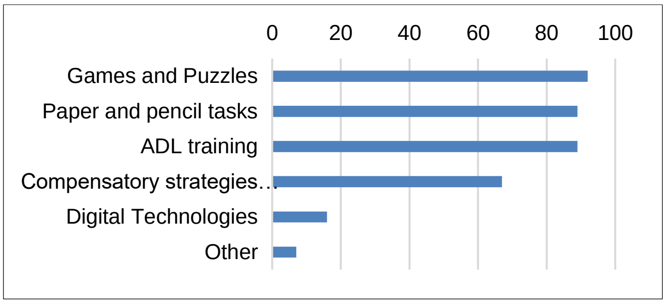


Figure 2. Activities used in current practice in CR.

3.4 *How are ITs currently used in CR?*

- *Use of ITs in current practices of CR.* 65.5% of the participants never used ITs in CR.
- *HPs’ opinions about the use of ITs in CR.* The different statements concerning the use of ITs in CR are presented in Figure 3. (The first four statements were only rated by participants that are currently using ITs in CR)

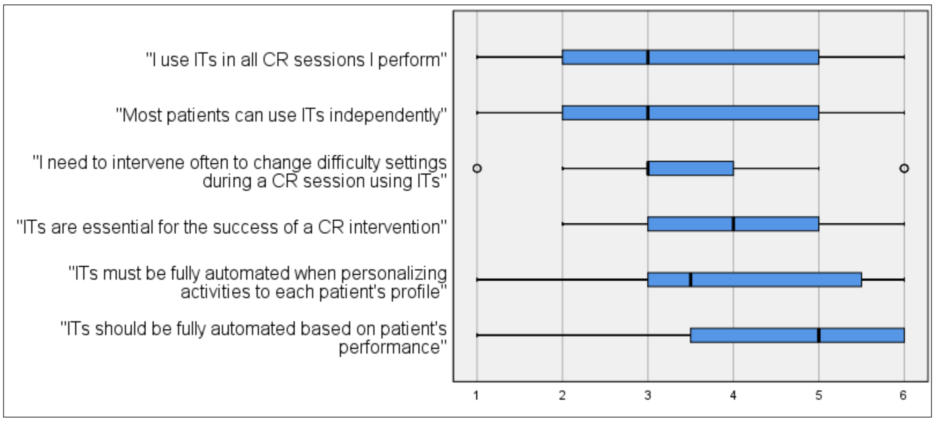


Figure 3. Median ratings on statements concerning the use of Its in CR.

- *ITs' characteristics.* When asked to rate the level of importance of different characteristics of ITs, participants rated high in all of the characteristics (Table 1).

Table 1. Importance of ITs characteristics.

ITs characteristic	***Mdn***	***IQR***
Visual appearance	5	2
Ease of interaction	6	1
Historical data visualization	5	2
Technology costs	6	1
Difficulty personalization to patient's profile	6	1
Difficulty adaptation based on performance	5	1
Content personalization	6	1
Diversity of activities	6	1
Portability	5	2
Data safety and security	6	1
Proof of evidence of efficacy	6	1
Integrated neuropsychological assessment	5	2

- *Reasons for not using ITs in current CR practices.* The inexistence of ITs at the institution was the most mentioned reason (N = 95) (Table 2).

Table 2. Reasons for not using ITs in CR.

Reasons for not using ITs in CR	***HPs without ITs experience (N=76)***	***HPs with ITs experience (N=40)***
Inexistence at the institution	67	28
Inexistence of ICT human resources at the institution	38	19
Lack of information	43	13
Preference for not using ITs	10	8
Institution regulations	9	6
Fear of technical issues	6	5
Lack of evidence of efficacy	6	3
Feeling uncomfortable with technology	8	6
No availability to learn new tools	3	4
Lack of interest for IT	4	3
Patient's inability to use ITs	3	3
Other reasons	2	2

3.4.5 What are the preferences in terms of at-home rehabilitation?

- *Prescription of ITs for CR at home.* 62.1% (N = 72) of the participants never prescribed ITs to be used at home. From those that already prescribed ITs to be used at home (N=44), 43.2% (N = 19) are not using them in current practice (Figure 4).

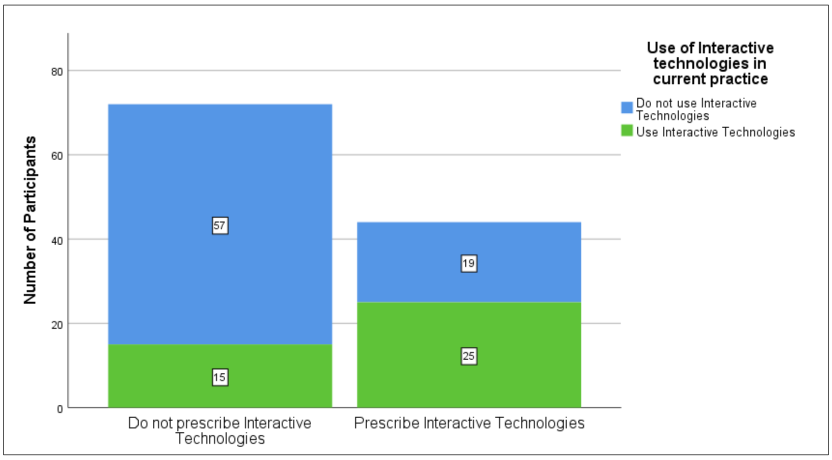


Figure 4. Prescription of ITs to be performed at home.

- *Preferred monitoring type.* 69% (N=80) of the participants answered that they prefer that the patient goes to the institution to be evaluated. 39.7% (N=46) answered that the patient could be monitored at home and only 6.9% (N=8) answered that monitoring could be done remotely through digital means.
- *Patient's independency to use ITs at home.* When comparing participants that already use ITs (Mdn = 3 (2)) and the ones that don't (Mdn = 2 (2)) on the statement: "Most patients are able to perform activities at home through ITs independently without assistance", participants that use ITs gave it a significantly higher rating (U = 1974, p = .006, r = .253).

3.5 What are the preferences of HPs concerning collaboration in the Design of ITs for CR?

88% of the participants (N=102) never collaborated in the design of ITs for CR. If to participate in the design process, the preferred method would be collaborative workshops (N=62, 53.4%). When asked to rate the level of importance of different entities/roles to participate in the design process, psychologists (Mdn = 6 (1)) and therapists (Mdn = 6 (1)) were the ones that obtained higher answers. 37 (31.9%) participants mentioned that they would like to participate in the design of ITs for CR.

4. DISCUSSION AND CONCLUSION

This study investigated the current practices in CR in Portuguese healthcare institutions and the opinions and expectations of HPs towards using ITs for CR. Results assist in characterizing demographically the HPs that are currently practicing CR in Portuguese healthcare institutions. Demographics are very similar to what was found in past studies, most are female occupational therapists aged 30-40 years old (de Joode et al., 2012). Contrary to the same study where only one-third of the participants reported to have treated patients with dementia, in our study, dementia was the most mentioned pathology. However, and aligned with literature (Stringer, 2010), stroke is in the top-three most mentioned, followed by Parkinson's disease.

Results show that ITs are not yet being widely used by HPs in CR sessions. Most participants (65.5%) did not have experience with ITs for CR. This is aligned with previous research where only 27,9% of respondents have reported previous experience with technologies in CR (de Joode et al., 2012). Since this study is from 2012, we would have expected that 8 years later, ITs would have had a higher percentage of use. It is important to highlight that for those reporting previous experience with ITs, these are essential to the rehabilitation success. Similarly, this is aligned with the same previous study where HPs with ITs experience agreed that technologies can be successfully used in CR.

From the participants that are already using ITs in current practice, only a few are prescribing them to patients to be used at home. Interestingly, some of the participants that do not have previous experience with ITs, are prescribing them to their patients to perform activities at home. Participants that have previous experience with ITs are more positive towards the use of ITs at home, and they display higher belief that most participants can perform the activities independently. This is also aligned with previous research where HPs with previous experience were more positive about their potential than those without experience (de Joode et al., 2012).

Among the difficulties and barriers in using ITs for CR, and contrary to previous research where participants responded that the price of technology and the lack of knowledge are the most mentioned reasons, in our study, the inexistence of ITs at the healthcare institution and the lack of human resources in ICT to give support are the major barriers for the use of ITs in CR. However, lack of information is the third most mentioned reason for not using ITs in CR, therefore, researchers should also focus on promoting the dissemination of information directly to health institutions and HPs and not only in scientific publications. Only a very small minority mentioned not having interest in ITs or no availability to learn new tools, therefore, this leads us to conclude that HPs are willing to learn and use ITs in CR if the health institutions make them available. Moreover, the patient's inability to use ITs was not considered a barrier to most of participants. Here we envision the opportunity for researchers, to invest also in finding systematic methods for delivering training for all stakeholders (HPs, caregivers, and patients), as also reported in other studies (Wang et al., 2016).

Finally, this study provided useful information about preferences for collaborative methods for the design of ITs for CR, in this case, a collaborative workshop was the most voted answer. This led us to organize a collaborative workshop with HPs, which results are currently being analysed.

As limitations from this study, our questionnaire did not address two important aspects. First, it would have been important to identify the most common cognitive problems addressed by HPs despite the pathology of the patient. This information would have been useful in finding which activities have more priority in being designed. Second, we didn't ask directly to the participants if they had willingness or interest in using/keep using the ITs for CR, and why. This would have helped in further understanding the reasons behind difficulties and barriers in using ITs.

Acknowledgements: The authors would like to thank all health professionals that answered the questionnaire. Special thanks to Ana Lúcia Faria for the feedback provided on the informal pilot. This study was supported by FCT through SFRH/BD/147390/2019 and PTDC/CCI-COM/30990/2017.

5. REFERENCES

Agüero-Torres, H., Thomas, V. S., Winblad, B., & Fratiglioni, L. (2002). The impact of somatic and cognitive disorders on the functional status of the elderly. Journal of Clinical Epidemiology, 55(10), 1007–1012. https://doi.org/10.1016/S0895-4356(02)00461-4

Baltaduonienė, D., Kubilius, R., Berškienė, K., Vitkus, L., & Petruševičienė, D. (2019). Change of cognitive functions after stroke with rehabilitation systems. Translational Neuroscience, 10(1), 118–124. https://doi.org/10.1515/tnsci-2019-0020

Carneiro, J. A., Cardoso, R. R., Durães, M. S., Guedes, M. C. A., Santos, F. L., Costa, F. M. da, & Caldeira, A. P. (2017). Frailty in the elderly: Prevalence and associated factors. Revista Brasileira De Enfermagem, 70(4), 747–752. https://doi.org/10.1590/0034-7167-2016-0633

Cicerone, K. D., Goldin, Y., Ganci, K., Rosenbaum, A., Wethe, J. V., Langenbahn, D. M., Malec, J. F., Bergquist, T. F., Kingsley, K., Nagele, D., Trexler, L., Fraas, M., Bogdanova, Y., & Harley, J. P. (2019). Evidence-Based Cognitive Rehabilitation: Systematic Review of the Literature From 2009 Through 2014. Archives of Physical Medicine and Rehabilitation, 100(8), 1515–1533. https://doi.org/10.1016/j.apmr.2019.02.011

Cumming, T. B., Marshall, R. S., & Lazar, R. M. (2013). Stroke, Cognitive Deficits, and Rehabilitation: Still an Incomplete Picture. International Journal of Stroke, 8(1), 38–45. https://doi.org/10.1111/j.1747-4949.2012.00972.x

de Joode, E. A., van Boxtel, M. P. J., Verhey, F. R., & van Heugten, C. M. (2012). Use of assistive technology in cognitive rehabilitation: Exploratory studies of the opinions and expectations of healthcare professionals and potential users. Brain Injury, 26(10), 1257–1266. https://doi.org/10.3109/02699052.2012.667590

Faria, A. L., Paulino, T., & Badia, S. B. i. (2019). Comparing adaptive cognitive training in virtual reality and paper-pencil in a sample of stroke patients. 2019 International Conference on Virtual Rehabilitation (ICVR), 1–7. https://doi.org/10.1109/ICVR46560.2019.8994746

Ferche, O.-M., Moldoveanu, A., Moldoveanu, F., Voinea, A., & Asavei, V. (2015). Challenges and issues for successfully applying virtual reality in medical rehabilitation. Conference Proceedings of »eLearning and Software for Education« (ELSE), 01, 494–501. https://doi.org/10.12753/2066-026X-15-073

Ge, S., Zhu, Z., Wu, B., & McConnell, E. S. (2018). Technology-based cognitive training and rehabilitation interventions for individuals with mild cognitive impairment: A systematic review. BMC Geriatrics, 18(1), 213. https://doi.org/10.1186/s12877-018-0893-1

Gustavsson, M., Ytterberg, C., & Guidetti, S. (2020). Exploring future possibilities of using information and communication technology in multidisciplinary rehabilitation after stroke – a grounded theory study. Scandinavian Journal of Occupational Therapy, 27(3), 223–230. https://doi.org/10.1080/11038128.2019.1666918

INE. (2019). Estatísticas Demográficas 2018. https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=404539341&PUBLICACOESmodo=2&xlang=pt

Maggio, M. G., Latella, D., Maresca, G., Sciarrone, F., Manuli, A., Naro, A., De Luca, R., & Calabrò, R. S. (2019). Virtual Reality and Cognitive Rehabilitation in People with Stroke: An Overview. The Journal of Neuroscience Nursing: Journal of the American Association of Neuroscience Nurses. https://doi.org/10.1097/JNN.0000000000000423

Morris, J., Jones, M., Thompson, N., Wallace, T., & DeRuyter, F. (2019). Clinician Perspectives on mRehab Interventions and Technologies for People with Disabilities in the United States: A National Survey. International Journal of Environmental Research and Public Health, 16(21). https://doi.org/10.3390/ijerph16214220

Nowell, C., Downing, M., Bragge, P., & Ponsford, J. (2019). Current practice of cognitive rehabilitation following traumatic brain injury: An international survey. Neuropsychological Rehabilitation, 0(0), 1–20. https://doi.org/10.1080/09602011.2019.1623823

Paravati, G., Spataro, V. M., Lamberti, F., Sanna, A., & Demartini, C. G. (2017). A Customizable Virtual Reality Framework for the Rehabilitation of Cognitive Functions. In A. L. Brooks, S. Brahnam, B. Kapralos, & L. C. Jain (Eds.), Recent Advances in Technologies for Inclusive Well-Being: From Worn to Off-body Sensing, Virtual Worlds, and Games for Serious Applications (pp. 61–85). Springer International Publishing. https://doi.org/10.1007/978-3-319-49879-9_4

Pariente, J. (2006). Effectiveness of rehabilitation for cognitive deficits. Journal of Neurology, Neurosurgery, and Psychiatry, 77(9), 1102. https://doi.org/10.1136/jnnp.2005.083477

Snoswell, A. J., & Snoswell, C. L. (2019). Immersive Virtual Reality in Health Care: Systematic Review of Technology and Disease States. JMIR Biomedical Engineering, 4(1), e15025. https://doi.org/10.2196/15025

SNS. (2020). Dispositivos Médicos por Nomenclatura Portuguesa do Dispositivo Médico. https://transparencia.sns.gov.pt/explore/dataset/dispositivos-medicos-por-nomenclatura-portuguesa-do-dispositivo-medico/

Stringer, A. Y. (2010). Cognitive Rehabilitation Practice Patterns: A Survey of American Hospital Association. The Clinical Neuropsychologist. https://doi.org/10.1076/clin.17.1.34.15625

Wang, J., Ding, D., Teodorski, E. E., Mahajan, H. P., & Cooper, R. A. (2016). Use of Assistive Technology for Cognition Among People With Traumatic Brain Injury: A Survey Study. Military Medicine, 181(6), 560–566. https://doi.org/10.7205/MILMED-D-14-00704

Wentink, M. M., VAN Bodegom-Vos, L., Brouns, B., Arwert, H. J., Vlieland, T. P. M. V., DE Kloet, A. J., & Meesters, J. J. L. (2018). What is Important in E-health Interventions for Stroke Rehabilitation? A Survey Study among Patients, Informal Caregivers and Health Professionals. International Journal of Telerehabilitation, 10(1), 15–28. https://doi.org/10.5195/ijt.2018.6247

Efficacy of adaptive cognitive training through desktop virtual reality and paper-and-pencil in the treatment of mental and behavioral disorders

J Câmara[1, 2, 3, 5], R Ferreira[1], L Teixeira, J Nóbrega[1], C Romeira[1], S B i Badia[3,4,5], A L Faria[3.5]

[1]Casa de Saúde Câmara Pestana

Rua do Lazareto, Funchal, Portugal

[2]Faculdade de Psicologia e de Ciências da Educação, Universidade de Coimbra

Rua do Colégio Novo, Coimbra, Portugal

[3]NOVA Laboratory for Computer Science and Informatics

Campus da Caparica, Caparica, Portugal

[4]Centro de Ciências Exatas e da Engenharia, Universidade da Madeira

Caminho da Penteada, Madeira, Portugal

[5]Madeira Interactive Technologies Institute, Universidade da Madeira

Caminho da Penteada, Madeira, Portugal

[1]joana.fcamara@gmail.com

ABSTRACT

In this work, we will assess and compare two content-equivalent cognitive training (CT) interventions delivered in desktop virtual reality (VR) (Reh@City v2.0) and paper-and-pencil (Task generator (TG)) formats in a sample of patients with mental and behavioral disorders. We found that both CT methodologies were associated with favorable cognitive, mood and quality of life outcomes observed in both the short (immediately after the intervention) and the long-term (two-months follow-up). We conclude that these CT methods should be viewed as complementary approaches in the treatment of mental and behavioral disorders.

1. INTRODUCTION

Cognitive deficits are a nuclear feature of mental and behavioral disorders, leading to poor treatment adherence and functionality (Rock et al., 2014). Therefore, cognitive deficits represent an essential target for intervention (Groves et al., 2018). Virtual reality (VR) methods can aid cognitive training (CT) in the context of psychiatry once they allow a more realistic training experience through the simulation of activities of daily living. VR-based interventions have several advantages over traditional paper-and-pencil methods, namely: the systematic and hierarchical presentation of stimuli and challenges; adaptation and personalization of training content to the patient's cognitive profile; immediate feedback; gaming elements to enhance motivation and engagement; increased ecological validity and, possibly, greater transfer of gains to everyday life (Faria et al., 2016; Gamito et al., 2015; Parsons 2016).

The main aims of this study are to assess and compare the impact of two-content equivalent CT interventions – the Reh@City v2.0 and the Task Generator (TG) – in a heterogeneous sample of mental and behavioral disorders recruited in a long-term care psychiatric setting.

2. METHODS

A total of 30 patients met the inclusion criteria and were randomly assigned to the Reh@City v2.0 group (n=15, two were lost to follow-up) and the TG group (n=15, one dropped out after the baseline assessment, and two were lost at follow-up). Both groups of patients underwent a time-matched 24-sessions CT intervention. Comprehensive neuropsychological assessments were conducted at baseline, post-intervention, and follow-up (2-months). We employed nonparametric tests to analyse the collected data.

3. RESULTS

A within-groups analysis revealed significant improvements in visual memory and depressive symptoms after the Reh@City v2.0 intervention, whereas the TG group improved in processing speed, verbal memory, and quality of life (social relationships and environmental domains). In the between-groups analysis, we found that the Reh@City v2.0 group showed a greater reduction in depressive symptoms, while the TG group exhibited higher improvements in social relationships aspects of quality of life. Considering the within-groups analysis at 2-months follow-up, both groups maintained the former gains, and new improvements were identified in the Reh@City v2.0 (global cognitive function, language, visuospatial and executive functions) and the TG groups (sustained and selective attention). The Reh@City v2.0 significantly reduced depressive symptoms, and the TG led to more significant improvements in processing speed, abstraction, and social relationships domain of quality of life.

4. CONCLUSIONS

Overall, patients from both groups revealed positive differential changes in primary (cognition) and secondary outcome measures (mood and quality of life) in the various assessment moments, which may suggest that the combined use of these two interventions could lead to higher short and long-term benefits in the assessed domains. The Reh@City v2.0 and the TG should be considered complementary CT methods for patients with mental and behavioral disorders living in long-term care psychiatric settings

Acknowledgements: This work was supported by the Fundação para a Ciência e Tecnologia (FCT) through the Belief Revision applied to Neurorehabilitation (BRaNT) project (PTDC/CCICOM/30990/2017), the Development and clinical validation of an adaptive cognitive training virtual tool for stroke patients project (SFRH/BD/145919/2019), which is a PhD grant awarded to Joana Câmara, and the MACBIOIDI projects (MAC/1.1.b/098), and by the NOVA Laboratory for Computer Science and Informatics (UID/CEC/04516/2019).

5. REFERENCES

Rock PL, Roiser JP, Riedel WJ, Blackwell AD, (2014), Cognitive impairment in depression: a systematic review and meta-analysis, *Psychol Med* 44, pp. 2029–2040.

Groves SJ, Douglas KM, Porter RJ, (2018), A Systematic review of cognitive predictors of treatment outcome in major depression, *Front Psychiatry* 9, pp. 1-20.

Faria AL, Andrade A, Soares L, Bermúdez i Badia S, (2016), Benefits of virtual reality based cognitive rehabilitation through simulated activities of daily living: a randomized controlled trial with stroke patients, *J NeuroEngineering Rehabil*, **1**, *13*, pp.1-12.

Parsons, TD, (2016), *Clinical neuropsychology and technology: what's new and how can we use it*, Springer International Publishing, Switzerland.

Gamito P, Oliveira J, Coelho C, Morais D, Lopes P, Pacheco J, Brito R, Soares F, Santos N, Barata, AF, (2015), Cognitive training on stroke patients via virtual reality-based serious games, *Disabil Rehabil*, 39, pp.385-388.

Road crossing behaviors of Pedestrians in two different Virtual Reality Environments

M. Asif Ahmad[1], Mónica S. Cameirão [1, 2]

[1,2] Faculdade de Ciências Exatas e da Engenharia & Madeira Interactive Technologies Institute, Universidade da Madeira Funchal, Portugal

[2] NOVA Laboratory for Computer Science and Informatics (NOVA LINCS), Lisboa, Portugal

[1]*muhammad.asif@m-iti.org*, [2]*monica.cameirao@m-iti.org*

[1,2]*www.uma.pt*, [1,2]*www.m-iti.org*, [2]*nova-lincs.di.fct.unl.pt*

ABSTRACT

About 20% of all people killed on roads are pedestrians. Virtual Reality (VR) simulators can be used to train street crossing and improve pedestrian safety, but the use of this technology has some limitations that need to be addressed. Common issues are related to the ecological validity of the experience because of poor immersion, movement limitations, and lack of visual and audio effects. In addition, these simulators are often very expensive. To address this, we developed a pedestrian street-crossing simulation that can be delivered through two mediums, a low-cost CAVE (Cave Automatic Virtual Environment) or a Head-Mounted Display (HMD). These two environments provide a high immersive experience, simple architecture, and a lower cost of deployment. Following an independent samples design, 20 participants were randomly allocated to the CAVE or HMD group and performed a street-crossing task. We measured the percentage of collisions with vehicles and presence through the Witmer and Singer Presence Questionnaire. Our results show that the percentage of collisions was significantly higher in the HMD group. Presence scores were high for both groups, but not significantly different. These results can be used to inform the design of VR simulators for safe street-crossing.

Keywords: Pedestrian Safety Simulator; VR Environments; User Experience; Pedestrian Behaviors

1. INTRODUCTION

The increasing number of vehicles and traffic in the last decades is leading to a higher number of casualties on the road, particularly of pedestrians that account for about 20% of all deaths in USA. In Europe, 5320 pedestrians were killed in road accidents in 2016, which corresponds to 21% of all road fatalities (European Commission, 2018). For the case of Portugal, in 2016-2017 there were approximately 10,000 accidents involving pedestrians (European Commission, 2017). A survey on pedestrian and bike rider activities in 2012 showed that some of the reasons for traffic accidents are related to low standard traffic services such as unavailability of footpaths and dark streets (Schroeder, 2013), and lack of traffic lights (Maillot et al., 2017). Interestingly, in 80% of the cases, the behavior of pedestrians is the cause of collision between vehicles and pedestrians (Lochhead, 2013). Therefore, more research is required to examine pedestrian behavior and to develop training procedures that could be used to train pedestrians (Dommes et al., 2017).

There are however limitations to conducting real-world studies on pedestrians such as creating a special risk-free traffic environment for an experiment and ensuring pedestrian safety. Moreover, every user has a different experience and behavior in real traffic environments, making it difficult to replicate such special traffic conditions. Virtual Reality (VR) based simulations have been used to train street-crossing, with the advantages of allowing safe environments that allow creating multiple traffic scenarios while preserving pedestrian safety (Deb et al, 2017). These traffic conditions are closely mapped to real-world traffic conditions in which pedestrians perform their actions. Several studies with VR simulation applications have been found to prevent pedestrian accidents (Schwebel, Gaines, & Severson, 2008) and to improve pedestrian safety (Bhagavathula, 2018). Nevertheless, these systems still have some limitations. One of the limitations is to create high quality virtual experiences that are realistic and immersive and that elicit presence (J. Hvass et al, 2017). And to create realistic experiences of street crossing in a limited space represents an additional challenge (Mallaro et al, 2017). To provide some examples, a study on child-pedestrian hazard perception skills used 180 spherical screens with three projectors to create a simulated dome projection environment where participants observed traffic scenarios while performing a hazard detection task (Meir, 2015). The results showed that when making street-crossing decisions, participants were more aware of hazards event with limited viewing angles, when compared to a control condition. Another study used a simulator which consisted of three projectors, an eye-tracking system, a photoelectric sensor, and an infrared light beamer, that used head and eye movements to record the decisions of pedestrians (Zito et al., 2015). Results from a street-crossing task with young and older adults showed that young participants were more conscientious during street crossing than older participants. Data of head and eye movements showed that this happened because older participants looked less at the sides of the street before crossing (Zito et al., 2015). Holland and Hill developed a similar virtual environment for recording collisions with vehicles, missed opportunities to cross the road, and attempts of road-crossings (Holland, 2010). In a study with 218 adults, the authors analysed if gender and/or age were factors modulating crossing decisions. The results showed women made more unsafe street crossing decisions as age increased, mainly because of limited mobility, but not men. Another VR simulator used real-traffic videos in a study with 359 participants that had to judge the speed of the oncoming vehicles to cross the road (Rosenbloom et al., 2015). Participants who were trained with the simulator achieved higher scores, and the results were modulated by age and gender. Men and young adults had higher scores compared to women and older participants (Rosenbloom et al., 2015). While showing interesting results, all the systems in these studies allowed only limited movement during crossings. To address this, Dommes and co-authors developed a virtual environment in such a way that participants could walk up to seven meters on an actual street of 5.7 meters in width (Dommes et al., 2017). This was achieved by using ten projector screens. Other studies used a CAVE (Cave Automatic Virtual Environment) and a treadmill to simulate road-crossings, but with the limitation that participants cannot step back (Banducci et al., 2016) (Nagamatsu et al., 2011). In one of these studies, the effect of dual-task performance was analysed in a VR environment in which participants crossed a virtual street by walking on treadmill while listening to music and talking on phone (Nagamatsu et al., 2011). The results showed that those who were at risk of falling had more collisions with oncoming vehicles during the dual-task.

When developing VR simulators for street crossing training an important feature for their ecological validity is their level of immersiveness and the sense of presence they can induce (J. Hvass et al, 2017) (Estupinan et al., 2014). Capturing these subjective measures is important to understand to what their effect is on the training of participants that use VR simulators. Some studies have assessed the level of presence elicited by VR simulators for street crossing, with CAVEs and Head Mounted Displays (HMD) providing experiences with a higher sense of presence and immersion compared to other VR systems (Deb et al, 2017) (Feldstein et al, 2016).

The main objective of our work is to develop a safe, easy to use, and low-cost VR environment to be used for road-crossing training. For this purpose, we developed a VR simulator deployed in two different setups, using a VR CAVE or a HMD. CAVEs and HMDs are considered highly immersive systems, provide realistic virtual environments of traffic conditions, besides minimizing space and movement constraints. We used a between-groups design to compare the efficacy of these two setups in increasing safety through reduced collisions. We also compared the perceived level of presence. We hypothesized that a user would have a higher sense of presence in the HMD condition when compared to the CAVE because the HMD is more immersive and because the user is more isolated from his/her surroundings. We also expected that participants in the HMD environment would have more valid road-crossing decisions (fewer collisions) considering that the virtual environment is more realistic.

2. METHODS

2.1 Participants

A convenience sample of 20 participants (10 females, ages: M=29.37 SD = 6.49) participated in this study. The participants were undergraduate and graduate students, and research assistants, that had no physical disabilities and were able to understand and speak English. All participants provided written informed consent and received no compensation for their participation.

2.2 Apparatus

For the development of our system, we used the Unity 3D game development platform (unity3d.com), which is a powerful tool to create 3D virtual environments. It has special features such as a particle system, animations, and physics for more realistic applications. We developed two different versions of the VR simulator for street crossing. The first used a CAVE environment previously developed at our research lab, which consists of four Hitachi projectors positioned in such a way as to project on the floor and walls (Gonçalves, 2018) (Fig. 1). The height and width of the CAVE walls were 2.2 and 2.8 meters, respectively. A Kinect V2 sensor was installed at the front wall to detect full body gestures. External speakers were used to add sound effects .

The second setup consisted of an HMD, namely an HTC Vive headset (vive.com) (Fig. 2). Vive renders stereoscopic textures of 3D models, which are generated at specific angles to create an immersive effect. Vive also has supporting features such as lighthouse sensors for tracking the position and rotation of the headset, allowing interacting with the virtual environment more efficiently. Our setup used two lighthouse sensors that were facing each other, placed at the corners of the CAVE. To help on preventing sickness, Vive provides a high refresh rate to reduce lag in rendering graphics.

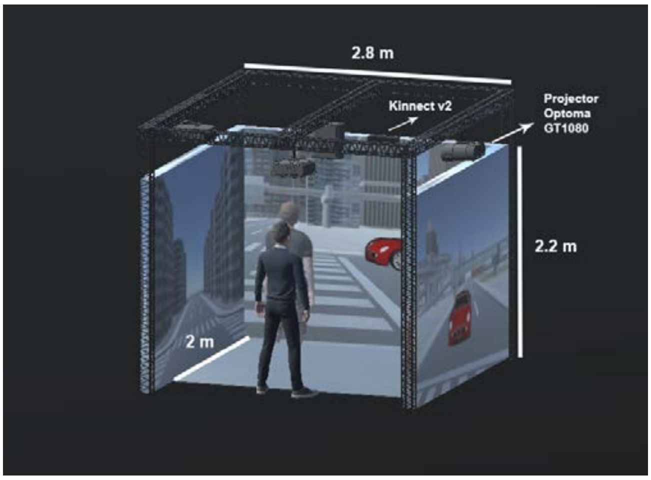


Figure 1. *CAVE setup*

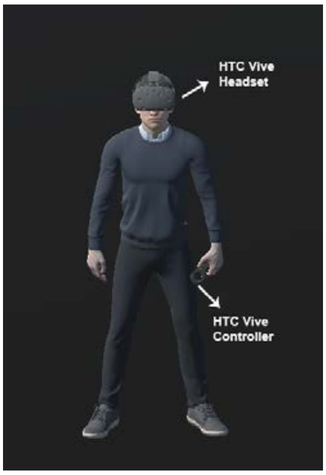


Figure 2. *HMD setup*

The VR environment simulates a 3D city with roads, downtown buildings, zebra-crossings, and traffic that simulated real-world conditions. The city environment was the same for both VR setups. Two different traffic speed limits were used, namely 40km/h and 60 km/h to assess how participants in behave in different speed limits, when they have a different gaps of time to cross (Fig. 3). Vehicles were spawned at different time intervals for the users to estimate valid gaps. A user could see his/her avatar in the VR environment, in front of him/her, standing at the curb of the footpath. Participants held a Vive controller that they should press when they decided to cross the road. The avatar walked at a speed of 1.20 m/s, which is the average speed of a pedestrian (FHWA, 2009). In case of a collision, or completion of the street-crossing session, the application re-spawned the avatar to the starting position.

2.3 Procedure

Participants were randomly allocated to one of the two conditions, HMD or VR CAVE. After being informed on the context of the study and signing the informed consent, the participants performed a training trial to familiarize themselves with the VR environment and to learn how to perform the task. After training, each participant executed two trials of 2 minutes each with different speed limits (40 km/h and 60 km/h). The number of times the avatar was hit by a vehicle (collisions) was recorded by the VR application. After the task, participants answered the Witmer and Singer Presence Questionnaire (WSPQ) (Witmer, 1998). The version used included 24 items addressing Involvement, Immersion, Visual Fidelity, Interface Quality and Sound (Witmer et al., 2005). Items 1-22 were rated on a 7-point scale. Sound items (20-22) were not included in the computation of the overall WSPQ score for comparison with other studies. Items 23 and 24 were removed because the application does not have haptics. A full session took about 10 minutes to be completed.

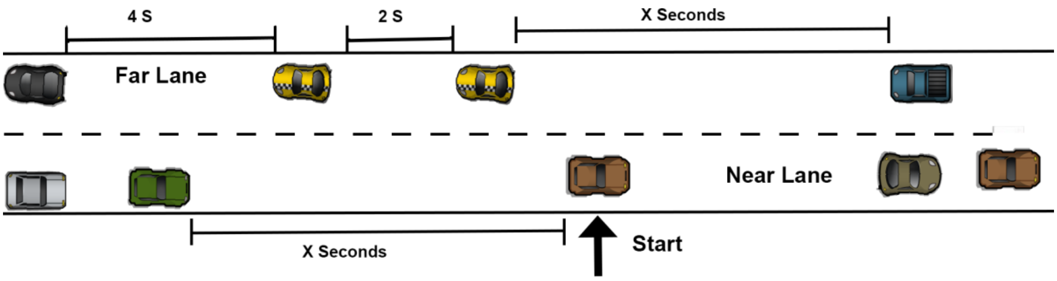


Figure 3. *Schematic Diagram of the Street Crossing Task*

2.4 Statistical Analysis

From the number of collisions, we computed the percentage of collisions for the two different speed limits, 40 and 60 km/h. The normality of the distributions was assessed using the Kolmogorov-Smirnov test. Data were considered normal for the 60 km/h speed limit, but not for 40 km/h. Hence, we decided to use nonparametric tests for both limits also because of the small sample size. Nonparametric tests were also used for the WSPQ because of its ordinal nature. For between-group comparisons, we used the 2-tailed Mann-Whitney test. Central tendency and dispersion measures are presented as median and interquartile range, respectively, Mdn (IQR). For the WSPQ, we present the mean (M) and standard deviation (STD) for comparison with the literature. The threshold for significance was set at 5% (α=0.5). Data were analysed using SPSS version 26.

3. RESULTS

The data of 1 participant was not included in the analysis because of technical difficulties with the setup during acquisition. For a sample of 19 participants, we compared the percentage of collisions between the two conditions (CAVE and HMD) for the speed limits (40 and 60 km/h) (Table1). When vehicles were moving at a speed of 40 km/h, participants in the HMD group displayed a significantly higher percentage of collisions when compared to participants in the CAVE group (CAVE: Mdn=0 (22.5), HMD: Mdn=50.0 (42.0); U=17.0, p=0.02, r=0.31). For a speed limit of 60 km/h, no significant difference was found between conditions (CAVE: Mdn=20.0 (33.0), HMD: Mdn=20.0 (31.5); U=41.5, p=0.77, r=.004) (Table 1) (Fig. 4).

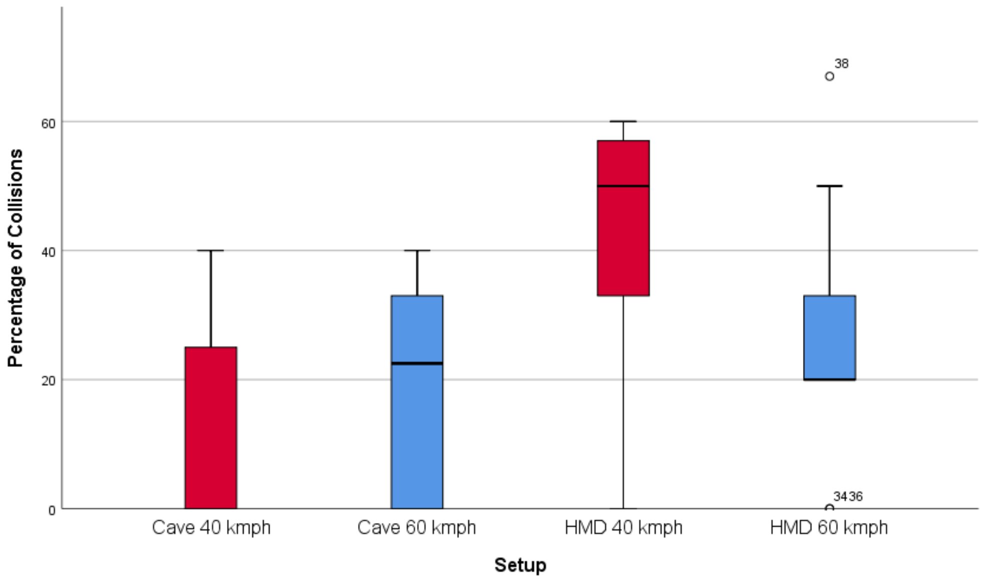


Figure 4. *Collisions in percentage for speed limit 40 and 60 kmph*

Table 1. *Median (IQR) percentage of collisions per condition*

Speed	CAVE (N=10)	HMD (N=9)	Mann-Whitney Test
40 km/h	0 (22.5)	50.0 (42.0)	U=17.0, p=0.02
60 km/h	20.0 (33.0)	20.0 (31.5)	U=41.5, p=0.77

The mean total score in the WSPQ for the CAVE group (M=122.7 (12.2)), although higher, was not significantly different from the HMD group (M=115.8 (17.5)), (U = 34, p=0.36, r=0.045) (Table 2). When analysing the separate items of the WSPQ, no significant differences were found between conditions (Table 2).

Table 2. *Mean (SD) scores in the Presence Questionnaire*

WSPQ	Items	CAVE (N=10)	HMD (N=9)
Total score	All execpt 20,21,22	122.7 (12.2)	115.8 (17.5)
Involvement	1,2,3,4,5,6,7,10,13	5.2 (0.6)	5.0 (1.2)
Immersion	8,9,14[a],15,16,19	6.1 (0.6)	5.6 (0.5)
Visual Fidelity	11,12	5.0 (1.1)	4.6 (1.3)
Interface Quality	17[a],18[a]	6.0 (0.9)	5.4 (1.9)
Sound	20,21,22	5.5 (1.2)	5.5 (0.8)

[a] Reversed items

4. DISCUSSION AND CONCLUSION

Here, we investigated and compared the efficacy for street crossing training and the user perception of presence of a VR environment deployed in two different setups: CAVE and HMD. Our results showed that the percentage of collisions is modulated by the speed at which vehicles were moving. With lower traffic speed, participants in the HMD group had a significantly higher percentage of collisions than those who were in the CAVE group. Fewer collisions indicate a more realistic environment that is more suitable to train pedestrians (Maillot et al, 2017). This could indicate that participants that used the HMD setup had more difficulties in deciding when to cross the street. The difference was, however, not significant at a higher speed (60 km/h). Although, HMDs have higher immersion than a CAVE, they might somewhat restrict looking at both sides of the street while wearing them. In contrast, the CAVE has larger screens and users can more easily look around. On the influence of the speed of the vehicles, it is important to note that pedestrians often judge the physical distance, not considering the speed, leading to poor estimation of the available time frame to cross the street. Other authors compared HMD with CAVE setups and found that participants took smaller gaps and performed faster in HMD when compared to the CAVE, suggesting that the HMD makes the scenario less threatening which leads to users taking more risks (Mallaro et al, 2017). This is plausible explanation to justify the higher number of collisions in the HMD setup. Another study where participants performed a train boarding task showed that the performance was better in a CAVE when compared to an NVIS nVisor ST HMD (Grechkinet al. 2014).

Concerning the WSPQ (Witmer et al, 1998), when comparing the total score over the 19-items in the two conditions, we observed that the mean score was slightly higher in the CAVE condition when compared to the HMD setup (122.7 (12.2) against 115.8 (17.5)), but not significantly different. Other studies that measured presence using the same version of this presence questionnaire on VR environments for pedestrians reported lower total scores. For example, a recent study reported a mean score of 109.35 (13.65) using a HMD (Deb et a, 2017). In another study, Feldstein et al reported total presence score of 93 (1.23) in an HMD setup (Feldstein et al, 2016). Our results indicate that both, the CAVE and the HMD, induced a stronger sense of presence when compared to the literature. On the subdomains of WSPQ, irrespective of the setup, we observed high scores for involvement and immersion indicating presence and realism of the virtual environment. We also observed high scores for visual fidelity and interface quality, suggesting the reliability of the simulator. The average score of sound also indicates realistic sound effects in the virtual environment for both setups.

Following the popularity of driving simulators, several studies developed pedestrian simulators through VR environments for street crossing training (Maillot et al., 2017). VR simulation has the advantage to train pedestrians in a safe environment that would not be achieved in a real traffic conditions. Our study compared the efficacy and presence of two VR environments by using the latest VR technology for pedestrian safety applications. Although the latest VR technology has removed barriers, there are still space constraints. To address this issue, our application represents the pedestrian as an avatar that the participant controls using a joystick/controller. This pedestrian simulator also includes sound effects to simulate real-world traffic experience. Both setups offer low-cost solutions with flexible and customizable traffic scenarios. But considering that the CAVE elicited a high sense of presence and taking into account that participants showed fewer collisions with vehicles, our results indicate that the CAVE is more effective as a simulator for street crossing.

The main limitation of this study is the small sample size and its lack of representativeness because all participants were young healthy adults. Children, elderly, and people with motor and/or cognitive deficits are at higher risk of being involved in traffic accidents. Hence, further studies should be done with these specific populations.

Acknowledgments: This study was supported by Fundação para a Ciência e a Tecnologia (FCT) through LARSyS – UID/EEA/50009/2019 and MITI Excell - M1420-01-0145-FEDER-000002l.

5. REFERENCES

Banducci, S.E., Ward, N., Gaspar, J.G., Schab, K.R., Crowell, J.A., Kaczmarski, H.,

Bhagavathula, Rajaram & Williams, Brian & Owens, Justin & Gibbons, Ronald. (2018). The Reality of Virtual Reality: A Comparison of Pedestrian Behavior in Real and Virtual Environments. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 62. 2056-2060. 10.1177/1541931218621464. Kramer, A.F., 2016. The effects of cell phone and text message conversations on simulated street crossing. Hum. Factors J. Hum. Factors Ergonomics Soc. 58 (1), 150e162.

Centers for Disease Control and Prevention. WISQARS (Web-based Injury Statistics Query and Reporting System). Atlanta, GA: US Department of Health and Human Services, CDC; 2015. Available at http://www.cdc.gov/injury/wisqars. Accessed 16 April 2018.

Deb, Shuchisnigdha & Carruth, Daniel & Sween, Richard & Strawderman, Lesley & Garrison, Teena. (2017). Efficacy of virtual reality in pedestrian safety research. Applied ergonomics. 65. 10.1016/j.apergo.2017.03.007.

Dommes, A., Le Lay, T., Vienne, F., Dang, N.-T., Perrot Beaudoin, A., Do, MC, 2015.Towards an explanation of age-related difficulties in crossing a two-way street. Accid. Anal. Prev. 85, 229–238, http://dx.doi.org/10.1016/j.aap.2015.09.022.

Estupi~nan, S., Rebelo, F., Noriega, P., Ferreira, C., Duarte, E., 2014. Can Virtual Reality Increase Emotional Responses (Arousal and Valence)? a Pilot Study. In Design, User Experience, and Usability. User Experience Design for Diverse Interaction Platforms and Environments. Springer International Publishing, pp. 541e549.

European Commission, Traffic Safety Basic Facts on Pedestrians, European Commission, Directorate General for Transport, June 2018.

European Commission. Traffic Safety Basic Facts on Urban areas 2017.

Feldstein, Ilja & Dietrich, Andre & Milinkovic, Sasha & Bengler, Klaus. (2016). A Pedestrian Simulator for Urban Crossing Scenarios. 49. 239-244. 10.1016/j.ifacol.2016.10.531.

Federal Highway Administration (FHWA), 2009. Manual on Uniform Traffic Control Devices (MUTCD).Retrieved from. http://mutcd.fhwa.dot.gov/kno_2009r1r2.htm.

Gonçalves, Afonso & Bermúdez i Badia, Sergi. (2018). KAVE: Building Kinect Based CAVE Automatic Virtual Environments, Methods for Surround-Screen Projection Management, Motion Parallax and Full-Body Interaction Support. Proceedings of the ACM on Human-Computer Interaction. 2. 1-15. 10.1145/3229092.

Holland, C., Hill, R., 2010. Gender differences in factors predicting unsafe crossing decisions in adult pedestrians across the lifespan: a simulation study. Accid. Anal. Prev. 42 (4), 1097e1106.

James, P., 2016, April 5. HTC Vive Review: a Mesmerising VR Experience, if You Have the Space. Retrieved from Road To VR http://www.roadtovr.com/htc-vivereview-room-scale-vr-mesmerising-vr-especially-if-you-have-the-spacesteamvr/.

J. Hvass, O. Larsen, K. Vendelbo, N. Nilsson, R. Nordahl, and S. Serafin. Visual realism and presence in a virtual reality game. In 2017 3DTV Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON), pp. 1–4, June 2017. doi: 10. 1109/3DTV.2017.8280421

Lamkin, P., 2016. The Best VR Headsets: the Virtual Reality Race Is on. Retrieved July,14, p. 2016.

Lochhead, C., 2013, August 13. Pedestrian Error Contributes to Fatal Crashes. Retrieved from Las Vegas Review Journal. http://www.reviewjournal.com/ news/crime-courts/pedestrian-error-contributes-fatal-crashes

Maillot, Pauline & Dommes, Aurélie & Dang, Nguyen Thong & Vienne, Fabrice. (2017). Training the elderly in pedestrian safety: Transfer effect between two virtual reality simulation devices. Accident Analysis & Prevention. 99. 161-170. 10.1016/j.aap.2016.11.017.

Mallaro, Sophia & Rahimian, Pooya & O'Neal, Elizabeth & Plumert, Jodie & Kearney, Joseph. (2017). A comparison of head-mounted displays vs. large-screen displays for an interactive pedestrian simulator. 1-4. 10.1145/3139131.3139171.

Meir, A., Oron-Gilad, T., Parmet, Y., 2015. Can child-pedestrians' hazard perception skills be enhanced? Accid. Anal. Prev. 83, 101e110

National Highway Traffic Safety Administration. Traffic Safety Facts, 2016 Data: Pedestrians. S. Department of Transportation, Washington, DC; 2018. Available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812493

Nagamatsu, Lindsay & Voss, Michelle & Neider, Mark & Gaspar, John & Handy, Todd & Kramer, Arthur & Liu-Ambrose, Teresa. (2011). Increased Cognitive Load Leads to Impaired Mobility Decisions in Seniors at Risk for Falls. Psychology and aging. 26. 253-9. 10.1037/a0022929.

Rosenbloom, T., Mandel, R., Rosner, Y., Eldror, E., 2015. Hazard perception test for pedestrians. Accid. Anal. Prev. 79, 160–169.

Schroeder, P., Wilbur, M., 2013. 2012 National Survey of Bicyclist and Pedestrian Attitudes and Behavior, vol. 1. Summary Report (No. DOT HS 811 841 A).

Schwebel, D.C., Gaines, J., Severson, J., 2008. Validation of virtual reality as a tool to understand and prevent child pedestrian injury. Accid. Anal. Prev. 40 (4), 1394e1400.

Timofey Y Grechkin, Jodie M Plumert, and Joseph K Kearney. 2014. Dynamic affordances in embodied interactive systems: The role of display and mode of locomotion.

IEEE Transactions on Visualization and Computer Graphics 20, 16 (2014), 596–605.

Whitebread, D., Neilson, K., 2000. The contribution of visual search strategies to the development of pedestrian skills by 4-11 year-old children. Br. J. Educ. Psychol. 70 (4), 539e557.

Witmer, B.G., Jerome, C.J., Singer, M.J., 2005. The factor structure of the presence

questionnaire. Presence 14 (3), 298e312.

Witmer, B.G., Singer, MJ, 1998. Measuring presence in virtual environments: a presence questionnaire. Presence Teleoperators virtual Environ. 7 (3), 225e240.

World Health Organization, 2013. More than 270 000 Pedestrians Killed on Roads Each Year. Retrieved from. http://www.who.int/mediacentre/news/notes/2013/ make_walking_safe_20130502/en/

Zito, G.A., Cazzoli, D., Scheffler, L., J€ager, M., Müri, R.M., Mosimann, U.P., Nyffeler, T. Mast, F.W., Nef, T., 2015. Street crossing behavior in younger and older pedestrians: an eye- and head-tracking study. BMC Geriatr. 15, 176

Enhancing Spatial Skills of Young Children with Special Needs Using Tangram Tangible Technology Versus a Tangram Card Game

O Lahav[1], A Wolfson[2]

Department of Mathematics, Science and Technology Education,
The Constantiner School of Education, Tel Aviv University,
Tel Aviv, ISRAEL

[1]*lahavo@tauex.tau.ac.il,* [2]*anawolfson@mail.tau.ac.il*

[1]*https://www.tau.ac.il/education/muse/orly/*

ABSTRACT

Spatial perception development in young children indicates readiness for school and predicts academic success in reading, arithmetic, science, and technology. The Tangram game is an ancient Chinese puzzle game and belongs to the "construction" games group. The Osmo tangible technology is based on reflective artificial intelligence which captures the user's physical actions in front of the screen in real time and transforms them into digital actions. In this research we conducted comparison research between children with special needs and children without special needs, preschoolers and kindergarteners, and examined their spatial ability while performing identical spatial tasks playing a Tangram card game versus playing an Osmo Tangram game based on tangible technology. In all sessions, the participants played individually without assistance. The research results were found to be statistically significant; the participants' performance with the tangible technology Osmo Tangram game was higher than with the traditional Tangram card game. Also, the participants' play duration with the tangible Osmo Tangram game was longer than with the traditional Tangram card game. These results demonstrate the ability of young children with and without special needs to play and to learn independently via the tangible technology Osmo Tangram.

1. INTRODUCTION

Use of digital technology in early childhood has clearly seen an increase in the 21st century. It is interesting to observe how this use affects learning processes, cognitive skills, and abilities among children and to study the impact of the gaming process using digital interface games compared to traditional games.

1.1 Cognitive development in early childhood

The cognitive process of early childhood development is affected by the environment in which children grow up, have experiences, and learn (Carson et al., 2016). This process is also affected by the quality of parental care, emotional and educational support, and nutrition (Lo, Das, & Horton, 2017). Apparently, early childhood is the stage at which children acquire the abilities that will form the basis of their development in a variety of areas during adolescence and adulthood. The more the young child experiences, explores, is exposed to stimuli, and practices values and beliefs, the more acute will be his or her perception, skills, and abilities later in life. These developmental steps will strengthen the child's problem-solving abilities and help him or her develop learning and decision-making strategies, independence, and the ability to understand sequences of actions and orientation in space (Palmer, Wehmeyer, & Shogren, 2017). The Israeli Ministry of Education (2007) suggests that, in order to develop these abilities at a young age, it is necessary to develop mathematical and spatial concepts as part of the learning curriculum and, in later childhood, to place learning in the context of social life skills.

1.2 Spatial perception in early childhood

Recent studies have found evidence of spatial perception in early childhood, such as identification of differences or similarities between objects, definition of personal and environmental space, spatial orientation, and the development of mathematical concepts. Experience of different activities in daily life combined with development of spatial skills seem to lead to the development of spatial perception among children at a young age. The more children play games intended to develop spatial perception, such as puzzles, dice, and board games, the more they appear to improve their spatial perception (Jirout & Newcombe, 2015).

Recent studies have shown that development of spatial perception in early childhood is important and even constitutes a basic component affecting the child's coping skills during the day (Baykal, Alaca, Yantaç, & Göksun, 2018). The development of spatial perception can contribute to the processes of problem solving, spatial orientation, planning and thinking strategy, understanding mathematical symbols and concepts, and visual working memory (Cheng & Mix, 2014). Improving the child's spatial perception and thinking abilities can be accomplished at any age through training (Hawes, LeFevre, & Bruce, 2015). In addition, these abilities form the basis for mathematical thinking and the development of the child's spatial abilities. Preschool children learn through play, which motivates children in the learning process and develops creative behavior (de Abreu & Barbosa, 2017). Thus it has been found that the use of game-based learning and digital interfaces encourages learning among preschool children, helping them to develop independence in the learning process (Garcia & Mangaba, 2017).

1.3 Game-based learning

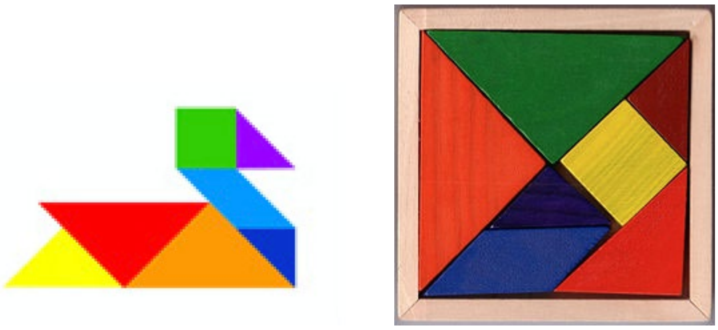
The use of games in general and game-based learning in particular motivates young learners and keeps them involved over the long term. Games enhance learning processes, strategies, and skills such as decision making, practical skills, and refinement capabilities (Ryan & Rigby, 2020). Among preschoolers, play is significant in learning about the components of their environment. These game experiences will accompany them later in life and will be helpful in dealing with challenges and problem solving, developing creativity and imagination, making connections, and understanding situations (Colliver & Veraksa, 2019). Games such as puzzles, dice, board games promote development of spatial perception and spatial skills (Jirout & Newcombe, 2015). Therefore, selection of games that the child will use for learning purposes should be tailored to the user's abilities and the learning goals.

It has been observed that the use of gaming applications in mobile devices and tablets has significantly replaced traditional gaming in the first years of preschool children (Oliemat, Ihmeideh, & Alkhawaldeh, 2018). Most preschool children see the tablet as recreational, for example, for watching videos and listening to music; they do not seem to define the tablet as a tool that encourages learning or to be used for educational purposes (Oliemat et al., 2018).

Recently a few game-based learning programs have been developed based on tangibles technology. Tangible technology is a platform that integrates technology with physical objects, where the user interacts with and manipulates the digital activity through physical objects (González-González, Guzmán-Franco, & Infante-Moro, 2019). The combination of the physical objects and the digital interface creates an innovative learning environment that creates new ways of concrete interaction with virtual and physical objects. This field has not yet been extensively researched, but early studies suggest a direct link between a tangible digital interface and the development of spatial concepts by children (Skulmowski, Pradel, Kühnert, Brunnett, & Rey, 2016). It has been found that interaction among children using a tangible technology game has the potential to mobilize them for active learning and creates a diverse play environment. This type of activity fosters a unique user experience, including employment of multiple senses in different types of interfaces, thus promoting innovative learning (Baykal et al., 2018).

The Tangram game is an ancient Chinese puzzle game and belongs to the "construction" games group (Figure 1). The user can play individually or with other players. The Tangram game includes seven colorful three-dimensional flat pieces (five different sized triangles, one square, and one parallelogram) and a variety of patterns to construct (from simple to complex, e.g., color, black and gray, and black). Through the game the user learns the spatial properties of the different pieces in relation to their location and orientation and cognitive rotation strategies. The aim of the game is to assemble a pattern from the colorful pieces.

Figure 1. *Traditional Tangram game (Tangram pattern on the right and the seven pieces on the left).*



Osmo designed its tangible technology games based on the traditional Tangram game (Figure 2). The Osmo tangible technology is based on reflective artificial intelligence, which captures the user's physical actions in front of the screen in real time and transforms them into digital actions. The tangible technology Tangram game provides tasks that are built upon the user's achievements; the user scores points and progresses through the stages of the game. Unlike the traditional Tangram, the Osmo Tangram provides immediate feedback during the assembly process. The tangible interface can also assist students with special needs in independent learning, using animation, acting, and auditory and visual feedback.

Figure 2. *Tangram game by Osmo.*

This study conducts a comparison of children's spatial ability in performing identical spatial tasks while playing a Tangram card game versus playing an Osmo Tangram game based on tangible technology. Our research aim was to explore whether the tangible user interface enhanced the spatial learning ability of young children. The research questions were:

1. What level of Tangram patterns did the participants from each research group attain using the Tangram card game compared to using the tangible technology Osmo Tangram game?

2. What was the duration of play in seconds for participants in each research group, comparing the Tangram card game and the tangible technology Osmo Tangram game?

2. METHODS

2.1 Participants

Thirteen young children participated in the current study. They were divided into two experimental groups: eight children with developmental disabilities and five children without special needs. All the children were four to six years old (M=5.25, SD=0.78). Participants in both experimental groups are integrated in regular preschool and kindergarten. Their parents or guardians signed a consent form.

2.2 Instrumentation

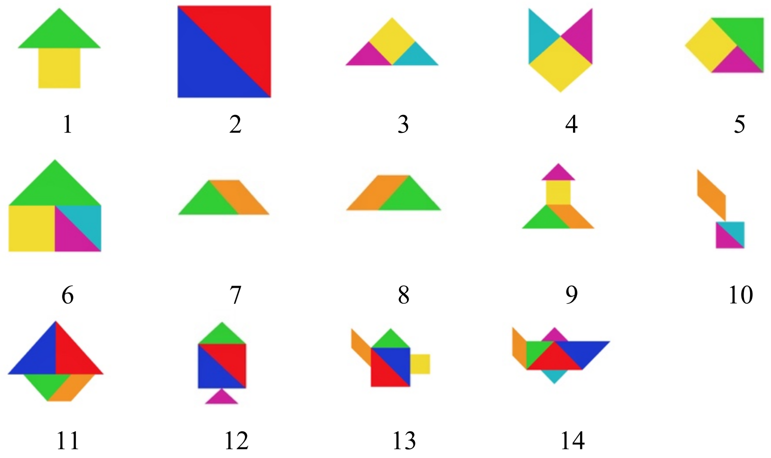
The research instrumentations included the traditional Tangram game, the tangible technology Osmo Tangram game, and observation as a data collection tool.

2.2.1 Traditional Tangram game. This set included the seven traditional pieces and 14 Tangram patterns that were chosen from the game. Each of the Tangram patterns was printed on a card. The 14 patterns progressed from a simple to a complex pattern; the complexity was defined by number of pieces, piece rotation, base configuration, and number of splits (Figure 3).

2.2.2 Tangible technology Osmo Tangram game. This set included an iPad, Osmo iPad base, reflector, seven Tangram pieces, and Tangram apps that included the same 14 patterns included in the traditional Tangram game (Figure 3).

2.2.3 Observation. All participants' interactions with the Tangram card and Osmo Tangram games were video recorded during all sessions.

Figure 3. *Tangram 14 patterns.*



2.3 Data processing and analysis

The data analysis of this study was based on the participants' interactions and performance with the traditional Tangram card game and the tangible technology Tangram game.

2.4 Procedure

The research was conducted in the participants' kindergartens or preschools (children with developmental disabilities) or at their home (children without special needs). After a parent signed the consent form, each participant individually received an explanation of the Tangram card game and played with it. The child was asked to place the Tangram pieces matching the target pattern on the card. The child played with the game until he or she did not wish to continue or did not succeed in performing the task. In the second session, a short video clip was presented, which explained how to play with the tangible technology Osmo Tangram game, followed by the participant's playing with the tangible game. As in the Tangram card game session, the participants played with the tangible Osmo Tangram game until they did not wish to continue or did not succeed in performing the task. In both sessions, the participants played individually without the assistance of another child or an adult. The length of each session was adjusted to the participant's needs, ability, and motivation; the session lasted a maximum of 40 min.

3. RESULTS

Research Question 1: What level of Tangram patterns did the participants from each research group attain using the Tangram card game compared to using the tangible technology Osmo Tangram game?

Each participant in each session (card or tangible) played with identical Tangram patterns in the same order of complexity (Figure 3). In order to examine the participants' performance with the Tangram patterns with the card game and the tangible technology Osmo Tangram game, a two-sample *t*-test was conducted. This test was found to be statistically significant (t (24) = 2.39, p =.025). The study results indicate that participants using the card game (*M*=6.8, *STD* =4.4) were able to construct (mean) with only the first six to seven cards of the patterns; only two subjects were able to construct all of the 14 patterns (participants with developmental disability). The mean score was similar for the two research groups: in the developmental disability participants group the mean score was the seventh pattern (range three to14 patterns) and the mean score for participants without disability was 6.6th pattern (range three to 12 patterns). Playing with the tangible technology Osmo Tangram game (*M*=10.8, *STD* =4.7), participants achieved a higher score than with the card game. In the tangible technology Osmo Tangram game, which included identical Tangram patterns, 95% of the participants were able to construct complex patterns; only one participant with developmental disability was unable to play with the tangible technology Osmo Tangram game. Six participants were able to construct all of the 14 patterns and another four participants were able to construct 10–13 patterns. The mean score among the developmental disability participants was 10.4th pattern (range zero to 14 patterns) and for participants without disability the mean score was 11.8th pattern (range five to 14 patterns).

Table 1. *Comparison of score level of Tangram patterns in card game and tangible Osmo game.*

	Card game		Tangible Osmo game		
	Mean	*STD*	Mean	*STD*	
Total (*N*=13)	6.8	4.4	10.8	4.7	*
Developmental disability (*N*=8)	7	4.5	10.4	5	
Without special needs (*N*=5)	6.6	4.1	11.8	3.9	

* $p<0.05$

Research Question 2: What was the duration of play in seconds for participants in each research group, comparing the Tangram card game and the tangible technology Osmo Tangram game?

In order to examine the participants' duration of play in seconds using both games, a two-sample *t*-test was conducted. This test was found to be statistically significant (t (24) = 3.16, p =.0042). The study results indicate that participants using the card game (*M*=3:57 sec, *STD* =130) played almost half the time compared with their duration of play with the tangible technology Osmo Tangram game (*M*=7:22 sec, *STD* =185). The duration mean duration of play with the Tangram card game for the participants with developmental disability was 3:46 sec (range 1:35–6:37 sec) and the mean score for participants without disability was 4:15 sec (range 1:23–7:52 sec). In the tangible technology Osmo Tangram game, most of the participants (92%) played for much longer with the tangible technology Osmo Tangram game. The mean duration of play with the tangible technology Osmo Tangram game for the participants with developmental disability was 7:06 sec (range 5:19–12:12 sec) and the mean score for participants without disability was 7:49 sec (range 3:08–10:00 sec).

Examination of the average duration to construct a pattern in the Tangram card game and the tangible technology Osmo Tangram game revealed close results: 35 sec to construct a Tangram card pattern and 40 sec to construct a Tangram tangible pattern. Similar results were found in the two research groups: the average for the participants with developmental disability was 32 sec to construct a Tangram card pattern and 41 sec to construct a Tangram tangible pattern. Less time was needed by the participants without disability: 39 sec to construct a Tangram card pattern and 40 sec to construct a Tangram tangible pattern.

4. CONCLUSIONS

This study adds to the theoretical knowledge about the use of tangible technology for spatial learning purposes by young children with and without disabilities. Exposure to spatial interaction in early childhood can develop basic abilities and skills for mathematical thinking and the development of spatial abilities. Such spatial activities motivate children during the learning process, contributing to their progress in the game and in the learning process (de Abreu, & Barbosa, 2017). In this study we examined the impact of exposure to spatial tasks in early childhood by children with and without special needs via the Tangram card game and Osmo Tangram game based on tangible technology. In this research, the participants' spatial activities through the tangible technology Tangram Osmo showed the children's higher performance compared to their performance in similar spatial activities using the Tangram card game. Our results resemble those of Palmer et al. (2017), who found that exposure to stimuli in early childhood will improve skills and abilities later in life. The Osmo tangible technology allowed the participants to interact with the different pieces and to construct complex shapes at different complexity levels.

As in Jirout and Newcombe (2015), all participants played with the Tangram card game and Osmo and developed spatial perception accordingly. Furthermore, the Osmo Tangram has the advantage of wrapping the spatial tasks as a game, allowing the participants in both research groups to learn and interact independently. These spatial activities using game-based learning on the iPad and concrete Tangram pieces encourage the participants' spatial learning, as also found by Garcia and Mangaba (2017) and Oliemat et al. (2018) in their research on the use of gaming applications in mobile devices and digital game-based learning.

The results of this study may form the basis for further research, for example a comparison of a large group of participants with and without disabilities, including longer exposure to Tangram spatial tasks to examine its impact on spatial perception. It would also be useful to examine the impact of the spatial activities using Osmo in different age groups, such as elderly people with and without special needs, as suggested by Hawes et al., (2015).

5. REFERENCES

Carson, V, Hunter, S, Kuzik, N, Wiebe, SA, Spence, JC, Friedman, A, ... & Hinkley, T, (2016), Systematic review of physical activity and cognitive development in early childhood. *Journal of science and medicine in sport*, *19*(7), 573-578.

Cheng, YL, & Mix, KS, (2014), Spatial training improves children's mathematics ability. *Journal of Cognition and Development*, *15*(1), 2-11.

Colliver, Y, & Veraksa, N, (2019), The aim of the game: A pedagogical tool to support young children's learning through play. *Learning, Culture and Social Interaction*, *21*, 296-310.

de Abreu, FM, & Barbosa, Á, (2017), Creative Engagement: Multimodal digital games in children's learning environment in Macau SAR. *Proceedings of the 8th International Conference on Digital Arts*, Saint Joseph, Macau, pp. 47-54.

Garcia, MB, & Mangaba, JB, (2017), Delivering Effective Digital Game-Based Learning: A Comparative Study Between Computer and Mobile as the Learning Framework for Preschoolers. *Paper presented at the 1st International Conference on Information Technology, Education, Engineering, and Management Sciences*., Turkey.

González-González, CS, Guzmán-Franco, MD, & Infante-Moro, A, (2019), Tangible Technologies for Childhood Education: A Systematic Review. *Sustainability*, *11*(10), 2910.

Hawes, Z, LeFevre, JA, Xu, C, & Bruce, CD, (2015), Mental rotation with tangible three-dimensional objects: A new measure sensitive to developmental differences in 4-to 8-year-old children. *Mind, Brain, and Education*, *9*(1), 10-18.

Jirout, JJ, & Newcombe, NS, (2015), Building blocks for developing spatial skills: Evidence from a large, representative US sample. *Psychological science*, 26(3), 302-310.

Lo, S, Das, P, & Horton, R, (2017), A good start in life will ensure a sustainable future for all. *Lancet (London, England)*, *389*(10064), 8.

Jirout, JJ, & Newcombe, NS, (2015), Building blocks for developing spatial skills: Evidence from a large, representative US sample. *Psychological science*, *26*(3), 302-310.

Oliemat, E, Ihmeideh, F, & Alkhawaldeh, M**,** (2018)**,** The use of touch-screen tablets in early childhood: Children's knowledge, skills, and attitudes towards tablet technology. *Children and Youth Services Review, 88*, 591-597.

Palmer, SB, Wehmeyer, ML, & Shogren, KA, (2017), The development of self-determination during childhood. In *Development of self-determination through the life-course* (pp. 71-88). Dordrecht: Springer.

Ryan, RM, & Rigby, CS, (2020), 6 Motivational Foundations of Game-Based Learning. *Handbook of Game-Based Learning*, 153.

Skulmowski, A, Pradel, S, Kühnert, T, Brunnett, G, & Rey, GD, (2016), Embodied learning using a tangible user interface: The effects of haptic perception and selective pointing on a spatial learning task. *Computers & Education*, *92*, 64-75.

Normative Data for a Next Generation Virtual Classroom for Attention Assessment in Children with ADHD and Beyond!

A Rizzo[1], J Z Chen[2], A Ma[2], J Wang[2], C-Y Chang[2], J Turnbull[3], C Shao[2]

[1]Institute for Creative Technologies, University of Southern California,

12015 East Waterfront Dr., Los Angeles, California, USA

[2]Cognitive Leap Solutions Inc.,

1110 S. Fifth Ave. Monrovia, California, USA

[3]Neurobehavior Services,

552 Crane Blvd., Los Angeles, California, USA

[1]rizzo@ict.usc.edu, [2]*jack@cognitiveleap.com,* [2]*aaron@cognitiveleap.com,* [2]*jwang@cognitiveleap.com,* [2]*kevin@cognitiveleap.com,* [3]*drturnbull@neurobehaviorservices.com,* [2]*charles@cognitiveleap.com*

[1]*ict.usc.edu,* [2]*www.cognitiveleap.com,* [3]*www.neurobehaviorservices.com*

ABSTRACT

Numerous researchers and clinicians have recognized the unique match between Virtual Reality (VR) technology assets and the requirements of various clinical assessment and treatment approaches and an encouraging body of research has emerged. In the area of cognitive assessment related to central nervous system dysfunction, traditional approaches often rely on paper and pencil psychometric tests, qualitative ratings of behavior, and flat screen computer tests to inform diagnosis and to track changes in clinical status. VR offers options for enhancing the assessment process beyond these methods with the creation of standardized immersive simulations within which user performance can be consistently measured under conditions that may be more relevant to the challenges present in the real world, to better inform diagnostic and treatment decisions. Similar to traditional methods, normative data from typical children can be accumulated from VR simulations that provide performance standards for comparison with that of atypical children. This presentation will initially discuss the history of the USC Virtual Classroom (VC) (since 1998) for testing attention processes in children with ADHD and other neurological conditions. This will be followed by the presentation of a new version of the VC and the results from a neurotypical standardization sample of 695 children (age 6-13) tested in the VC. Ongoing data collection from children with attention impairments will be discussed in the context of the development of this research program.

1. INTRODUCTION

The USC VC project commenced in 1998 with the initial aim to explore the feasibility and usefulness of VR as a tool to assess children with ADHD within ecologically relevant and systematically controllable stimulus conditions. The rationale for this effort was also bolstered by the idea that movement data could be easily collected leveraging the on-board head and body tracking technology that was naturally part of the implementation of VR. Movement was thought to be an area of assessment often neglected in standard psychometric tests, but vitally relevant to making an informed assessment of the hyperactivity component of ADHD. In 2003, after cognitive and movement data from an initial clinical trial documented the value of this approach for differentiating children with ADHD from neurotypicals, a commercial test publisher supported efforts to productize the application. However, primarily due to the cost of VR equipment at the time and the general unfamiliarity with the technology by practicing clinicians, the product development effort was discontinued and the resulting VC reverted to becoming a tool for cognitive/clinical research by academics. In 2018, as low cost and high fidelity VR technology became more readily available and with the accumulation of positive findings over more than 20 studies

Parson & Rizzo, 2019), it was decided that the VC would undergo an update with the aim of promoting its wider distribution as a commercial product. In partnership with a commercial entity, Cognitive Leap, a new VC was created, informed from knowledge gained from previous research with the various USC versions. Similar to traditional testing approaches, data collected across different neurotypical age groups was needed to establish a normative database. This was essential for creating the standards by which the performance of children suspected of having ADHD could be compared. The results of that effort are detailed next.

Images 1-2. *Virtual Classroom (L) and Users interacting with the system (R).*

2. METHOD

Six hundred and ninety-five, non-diagnosed, typical children (female n=321) across the ages of 6-13 were tested on a 13-minute VC test to establish normative data for each age group. Children were evaluated on an A-K continuous performance task delivered on a white board within the VC, while common distractions (typical of a regular classroom) were also presented. Key performance variables that were measured included Omission Errors (O), Commission Errors (C), Reaction Time (RT) and Reaction Time Variability (RTV). Head Movement variables were also recorded from the VIVE HMD tracking system during the test sessions to document behavior related to hyperactivity and distraction.

3. RESULTS

Results from this normative sample showed clear linear performance improvements on all variables across the ages of 6-13, as was predicted across this developmental period. For example, when grouped by 2-year intervals, male participants showed a reduction of both omission (O) and commission (C) errors across the age groupings (for ages, 6-7, 8-9, 10-11, and 12-13, mean O's = 13.6, 6.6, 4.2, and 2.1, and mean C's = 22.5, 12.1, 5.4, and 2.9, respectively). Moreover, reaction time and reaction time variability produced similar reductions (mean RT's (in msecs.) = 523, 450, 407, and 402, and mean RTV's = 197, 149, 124, 110, respectively). Results for female participants followed the same linear pattern.

4. CONCLUSIONS

These findings provide support for the VC's capability to capture performance change over this span of early childhood development. More data from this normative dataset and its importance for making comparisons with children with ADHD will be presented at the conference. At the current time, the VC is in use at three clinical sites to collect performance data on children diagnosed with ADHD, off of their medications during the testing to allow for performance comparisons with the normative sample. At the same time, variations on the VC classroom are being explored to address other cognitive processes and clinical populations. Auditory attention tasks and an adult version of the VC will be used to expand the range of use for this application concept.

5. REFERENCES

Parsons, TD and Rizzo, A. (2019) A Review of Virtual Classroom Environments for Neuropsychological Assessment. In: *Virtual Reality for Psychological and Neurocognitive Interventions*. (A Rizzo & S Bouchard, Eds), Springer, New York, NY. pp 247-265.

Virtual Environment Grocery Store (VEGS) for assessing memory in persons with epilepsy: A Comparative Study on the Predictive Ability of the Support Vector Machine, K-Nearest Neighbours, and Naïve Bayes

T McMahan[1,2], T Duffield[3], T D Parsons[1,2]

[1] College of Information, University of North Texas,
3940 N Elm St, Denton, Texas, UNITED STATES

[2] iCenter for Affective Neurotechnologies (iCAN),
3940 N Elm St, Denton, Texas, UNITED STATES

[2] Department of Family/Sports Medicine, Oregon Health & Science University
Portland, Oregon, UNITED STATES

[1]*Timothy.McMahan@unt.edu*, [2]*Thomas.Parsons@unt.edu*, [3]*duffielt@unt.edu*

[1] *https://ci.unt.edu/,* [2] *https://ican.unt.edu/,* [3] *https://www.ohsu.edu/*

ABSTRACT

Everyday memory performance in persons with epilepsy is rarely assessed in real-world situations (e.g., outside the clinic). Virtual reality-based neuropsychological assessments offer the potential to address the limited ecological validity of pen-and-paper measures of memory. Studies have found the Virtual Environment Grocery Store (VEGS) to be a psychometrically valid assessment of memory and executive functioning. While advances in virtual reality-based assessments provide potential for increasing ecological validity in the evaluation of cognitive processes, less has been done to develop these simulations into adaptive virtual environments (AVE) for improved neurocognitive assessment. Adaptive assessments offer the potential for dynamically adapting the difficulty level specific to the user's knowledge or ability. This study aimed to assess cognitive performance classifiers with data from participants (N=82) who had been immersed in the VEGS. Three machine learning approaches were used to accurately classify participants diagnosed with epilepsy. First, Support Vector Machines (SVM), Naive Bayes (NB), and k-Nearest Neighbours (kNN) were trained using data collected from nonclinical participants. Second, the classifiers (SVM; NB; kNN) were applied to data collected from participants with epilepsy. Training data categorized participants into high performing or low performing categories. Using the training data on nonclinical participants revealed that the classifiers produced the following results: SVM - 95% correct classification, kNN - 90%, and NB – 60%. When using these classifiers to correctly classify participants with epilepsy (N = 6) as either high performers or low performers the most robust classifier was the kNN (100% correct classification). Both SVM and NB were able to correctly categorize 83% of the time. The results of the study revealed that the classifiers are capable of classifying individuals with epilepsy into the correct category. Knowing if a participant falls into a low performing category will help determine if the VEGS should adapt to personalize the environment relative to the participant's capacity for performing activities of daily living.

1. INTRODUCTION

Learning and memory impairment on traditional paper-and-pencil clinical neuropsychology assessments is common in persons with epilepsy (Bouman et al., 2016; Helmstaedter & Elger, 2009). That said, everyday memory performance in persons with epilepsy is rarely assessed in real-world situations (e.g., outside the clinic). Virtual reality-based neuropsychological assessments offer the potential to address the limited ecological validity of pen-and-paper measures of memory (Bohil et al., 2011; Kothgassner & Felnhofer, 2020; Parsons, 2015). While advances in virtual reality-based assessments provide potential for increasing ecological validity in the evaluation of cognitive processes, less has been done to develop these simulations into adaptive virtual environments (AVE) for improved neurocognitive assessment. Adaptive assessments offer the potential for dynamically adapting the difficulty level specific to the user's knowledge or ability.

The Virtual Environment Grocery Store (VEGS) is a virtual reality platform designed to immerse users allowing them to interact with items and virtual avatars while completing shopping tasks (see Figure 1). VEGS can assess specific neuropsychological measures include learning, memory, navigation, and executive functions. Users perform a various task while navigating the virtual store: traveling from the store entrance to back of the store where the pharmacist is located; interact with the virtual human pharmacist and drop off their prescription. The virtual human pharmacist gives the user a number that they must listen for while shopping (see Figure 2). While shopping, announcements are made over the stores broadcast system. The user must listen to the announcement for their number, and disregard other numbers while shopping (cognitive inhibition: ignoring other numbers). The participant is directed to collect items from a shopping list that they learned preceding immersion. Participants are also directed to navigate to a coupon machine after two minutes (time-based prospective memory).

The VEGS also incorporates other tasks: traversing through the aisles; choosing and retrieving items from the shopping list (List Items); disregarding items not on the shopping list (Intrusions); and staying within budget (Budget Score). The user returns to the pharmacist after hearing their prescription number called. Once back at the pharmacy they must wait in line to pick up their prescription from the virtual pharmacist (event-based prospective memory). After the user's immersive experience in the VEGS, the participant completes delayed free and cued recall of the VEGS shopping items. Latest efforts at psychometric validation of the VEGS have uncovered it to have construct validity for evaluating both older and younger aged adults in both high and low distraction conditions (Parsons & Barnett, 2017; Parsons& McMahan, 2017). The VEGS looks to be mainly a memory (episodic and prospective) assessment in the lower distraction conditions. Adding environmental distractors (e.g., additional avatars; more announcements; cell phones ringing) showed that users' performance was linked to both memory and executing functioning measures (Parsons & Barnett, 2017; Parsons& McMahan, 2017). While studies have found the Virtual Environment Grocery Store (VEGS) to be a psychometrically valid assessment of memory and executive functioning, these former iterations of the VEGS did not adapt to user performance.

Figure 1. *The Virtual Environment Grocery Store*

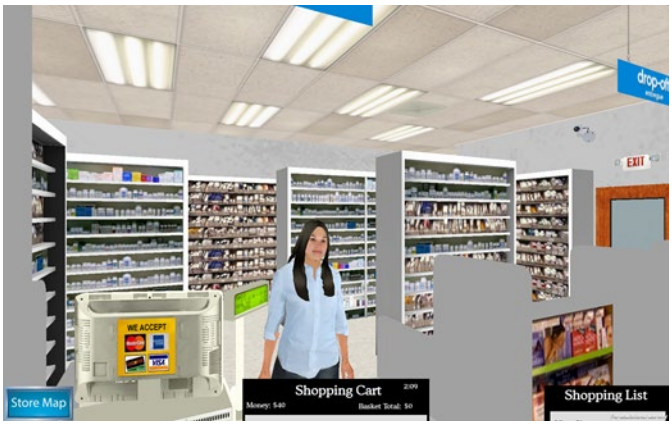


Figure 2. *Pharmacist in the Virtual Environment Grocery Store (gives participant a prescription pick-up number).*

Figure 3. *Entry point of the Virtual Environment Grocery Store platform*

2. METHODS

The research obtained authorization from the university's committee for the protection of human subjects.

2.1 *Participants*

Data was collected from 2 different sources. The first source was from 76 college students. The participants involved must be aged 18 years or older and have normal (to corrected) vision. Participants would be omitted if they had a record of psychiatric condition(s), attention-deficit/hyperactivity disorder, or other Axis I psychopathology (diagnosed or suspected). Participants were not involved if they had a history of epilepsy, intellectual disability (IQ < 70), and/or neurological impairments impacting cognitive and/or motor movements. No participants were excluded from this group of participants. The second source of data was from 6 participants that have been diagnosed with epilepsy. The participants were aged 17 and older, had normal (to corrected) vision, and had no issues with controlling movements. The participants do suffer from other psychological problems such as anxiety and depression. The participants reported that they did not avoid computers and were mostly experienced or very experienced when working with computers.

2.2 *Apparatus* and Measures

2.2.1 *Procedure.* Each participant participated in a 90-minute experimental session that included data collection. Each participant was briefed on the study's procedures, potential risks, and benefits upon arriving at the lab. Every participant was given the option to discontinue the session at any time. Upon being briefed about the study, each participant signed a written informed consent (approved by the university's institutional review board) that signified their approval to take part in the experimental session. Before the participant entered the virtual environment, general demographic data was collected and participants answered questions intended to measure their overall computer skill, comfort, and usage activities, perceived level of computer skill (Likert scale (1–not at all to 5–very skilled); and the types of video games they played (e.g., role-playing; eSports, etc.). No significant differences were found for overall computer skill. Participants completed a simulator sickness questionnaire (Kennedy et al., 1992), which includes pre- and post-VR exposure symptom checklists. No significant simulator sickness was noted.

2.2.2 *Virtual Environment Grocery Store*. The VEGS (see Figure 3) was run on a PC with an Intel Core i7 processor, 16GB ram, NVIDIA GeForce GTX 1060 graphics card and the Windows 10 operating system. The VEGS can utilize multiple head mounted displays (HMDs), for this study the HTC Vive (http://www.htcvive.com) was used. The HTC Vive runs at a resolution of 2160 x 1200 on an organic light-emitting diode (OLED) display with a refresh rate of 90 Hz. The VEGS incorporates several ordinary shopping activities that have been discovered to be correlated with cognitive performance on traditional (low-dimensional) neuropsychological assessments.

Preceding the start of VEGS, users participated in an encoding phase in which they learned the list of shopping items that they would shop in VEGS. The encoding phase required the participants (not immersed) to learn trials aimed at conveying the shopping items needed once they started VEGS. The examiner read off out loud to the participants 16 items (the examiner made sure there was a two second inter-stimulus interval between each word read out loud. Participants were not ever allowed to see the shopping list. Upon completion of the examiner reading of the list, the participant was directed to name the items from the shopping list in any order. The participant's responses to the immediate recall of items were recorded by a microphone and was logged for each of the immediate recall trials (Trials 1–3).

At the completion of the encoding phase, participants took part in a familiarization phase, which allowed them to become immersed in the virtual environment and learn the controls, navigation, and how to select items from the shelves. The length of the familiarization phase (on average from 3 to 5 minutes) was decided by the participant's stated comfort and prior familiarity with virtual reality platforms. Prior to the begging of the test phase, the examiners verified with the participant that they were proficient at using the controls and answered any participant questions. Finally, the participant was advised of the tasks they needed to complete during the testing phase: first, the participant would have to travel to the pharmacy at the back of the store and interact with the pharmacist to drop off their prescription. Once they clicked on the pharmacist, they would be given a number to remember and instructions; 2) participants need to listen for their number to be called (ignoring any other announcements) as they shopped for items from the shopping list they learned during the encoding phase; 3) participants were requested to monitor the time and after 2 minutes to navigate to the coupon machine and obtain a coupon (time-based prospective memory); and 4) once their prescription number was called, they should return to the pharmacist immediately and click on the pharmacist for pick-up their prescription (event-based prospective memory). Upon acknowledging the understanding of the instructions, the VEGS protocol started.

2.2.3 *Data Analytic Considerations.* Statistica version 13.3 was used for all analyses. Descriptive statistics were assessed for VEGs predictor variables and participant demographics. For any variables with missing data, case-wise deletion was used. Machine learning predictor variables were identified from the participant data (see Table 1). Knowing a user's performance level allows for adaptation of the VEGS environment to adjust and enhance the user experience. The criteria for choosing predictor variables were based upon if that variable could be utilized in the adaptive environment to deliver the machine learning algorithm with predictions of participant performance levels in real time.

After identifying the prediction variables, descriptive statistics were computed for each predictor (see Table 1). As a note, when considering Table 1 the range of performances indicate high and low performance categories. As an example, "# of times looked shop list" ranges from high performance (looked at shopping list in VEGS one time) to low performance (participant looked at shopping list 469 times—which means that participant constantly looked at the shopping list throughout the task). Likewise, with the timing some participants were high performers and completed tasks quickly, while other low performers took greater amounts of time. These were included in the model to establish classifiers for high and low performance.

Table 1. *Machine Learning Predictor Variable Descriptions and Descriptives*

Predictor Variables	Description	Mean	SD	Min	Max
# of times looked shop list	Number of Times the participant viewed the shopping list.	60.2	67.3	1	469
Prescription Drop Off Time	Time in seconds that the participant dropped off their prescription	126.6	195.5	39.4	1718.2
Time Spent Shopping	Total time in seconds the participant spent shopping	638.3	45.3	602.9	848.2
ATM Withdraw Time_1	Time in seconds that the participant visited the ATM	488.1	185.2	331.2	1849.8
Nutrise_Time	Time in seconds that the participant picked up Nutrise product.	527.7	255.8	158.9	2192.1
Magazine_Time	Time in seconds that the participant picked up Magazine product.	516.6	92.7	241.3	848.4
M&Ms_Time	Time in seconds that the participant picked up M&Ms product.	369.2	110.1	128.8	880.8
Glad_Time	Time in seconds that the participant picked up Glad product.	467.5	62.1	157.8	679.6
Batteries_Time	Time in seconds that the participant picked up Batteries product.	473.0	263.3	13.49	2342.0
Vitamin D_Time	Time in seconds that the participant picked up Vitamin D product.	524.1	274.1	98.1	2270.3
Raisin Bran_Time	Time in seconds that the participant picked up Raisin Bran product.	435.9	84.8	195.7	655.4
Fritos_Time	Time in seconds that the participant picked up Fritos product.	481.8	135.3	147.7	894.1
Pepsi_Time	Time in seconds that the participant picked up Pepsi product.	413.3	131.2	136.8	750.8
BPT_Time	Time in seconds that the participant picked up Paper Towels product.	516.6	164.8	103.4	1499.8
Lightbulb_Time	Time in seconds that the participant picked up Lightbulb product.	513.8	56.1	271.5	679.0
Tylenol_Time	Time in seconds that the participant picked up Tylenol product.	540.5	192.3	155.6	1805.7
Shampoo_Time	Time in seconds that the participant picked up shampoo product.	375.5	145.6	69.9	985.5
Listerine_Time	Time in seconds that the participant picked up Listerine product.	407.3	155.2	83.9	785.0
Soap_Time	Time in seconds that the participant picked up Soap product.	426.0	89.5	203.3	729.8
BandAid_Time	Time in seconds that the participant picked up Band-Aid product.	481.5	245.5	94.4	2257.4

For the study, participants were categorized as either a high performer or a low performer. To place each participant in their correct category we utilized the number of items that every user was able to locate throughout the shopping phase, the mean was computed (Mean = 7.5 items). A participant was designated as a high perform if the number of items they found was larger than the mean and designated as a low perform if the total number of items found was smaller than the mean. The category distribution was 38 high performers to 38 low performers.

1) Support Vector Machine: The support vector machine (SVM) employs a hyperplane to slice the data into two classes when categorizing binary data. The SVM trains on data in both categories and tries to categorize them into a higher dimensional space. The objective of the SVM is produce a hyperplane that generates a maximum space between the two groups. Upon completion of training, the SVM uses testing data and positions it into one of the two groups. SVM makes the determination to which category the test data belongs based upon what side of the hyperplane the data fall. This study implemented a Type 2 classification using 0.5 Nu with a radial basis function kernel (gamma = 0.016). The maximum number of iterations was set to 1000 with a stop error of 0.001. 10 v-fold cross validation was used for segmenting and testing the data.

2) Naïve Bayes: Based upon Bayes theorem, the Naïve Bayes (NB) classifier is ideal for situations in which the dimensionality of inputs is high. NB offers an advantage in that it does not need a large set of training data. The NB classifier utilizes a computed probability that a set of data point fits into a class. The NB algorithm tries to classify by selecting the highest probability as its outcome. NB presumes that each predictor is independent from other predictors. A feature vector is computed for each group throughout the training phase. NB uses maximum likelihood during the testing phase for categorizing the data into correct categories. In this study, 10 v-fold cross validation was used for data segmentation of training and testing data. A normal distribution was assumed for each predictor.

3) k-Nearest Neighbor: k-Nearest Neighbor (kNN), applies position to ascertain data categorization. The kNN utilizes feature vectors to maintain the category's datum throughout the training phase. When presenting kNN with new data it computes the shortest distance to the one of the categories. In this study, 10 v-fold cross validation was used to segment the data for the kNN classifier which used a Cityblock (Manhattan) distance measure.

3. RESULTS

Predictors (see Table 1) were used to classify participants into either a high performer category or a low performers category using Support Vector Machine (SVM), Naïve Bayes (NB), and k-Nearest Neighbor (kNN) classifiers (see Table 2). Using 10 v-fold cross validation the 76 participant's data was segmented into 68 algorithm training samples and 8 algorithm testing samples. The participants' samples include 20 data points that were utilized as predictors for the machine learning algorithms.

Initially the classifiers were only trained and tested using data from the nonclinical participants. The classifier that performed the best was SVM, which yielded an accuracy rate of 95%, followed closely by kNN (90%). NB fell in last yielding an accuracy of only 60%. kNN did yield a better precision and sensitivity over both SVM and NB. The better precision and sensitivity suggest that kNN is superior at accurately designating high performing participants than SVM which was superior at designating low performing participants (see Figure 4). The kNN algorithm is favoring high performers over the low performers. NB poor classification accuracy may be attributed to the dataset not being Naïve or the possibility that not all the predictors are independent of each other.

The next part of the research study was to test the classifiers using the data collected from the participants with epilepsy. All the data collected from the nonclinical participants was used to train the machine learning algorithms. Once trained each classifier was tested with the clinical test data to identify how well it could correctly classify the participants into the correct category. The classifier that performed the best was kNN which achieved a 100% correct classification rate. Both SVM and NB were able to correctly categorize 83% of the time. All the epilepsy patients were classified into low performer category. kNN success can most likely be attributed to the majority of the data being significantly furthest away from the high performers group data. While SVM and NB performed below kNN they still achieved acceptable accuracy as they only miss categorized one participant whose data was borderline close to being a high performer.

Table 2. *Machine Learning Classifier Results*

Machine Learning	Accuracy	Misclassification	Precision	Sensitivity	Specificity	F-Measure
SVM - nonclinical	95%	5%	90%	90%	100%	0.95
kNN - nonclinical	90%	10%	100%	100%	80%	1.0
NB - nonclinical	60%	40%	80%	80%	40%	0.8
SVM - clinical	83%	17%	83%	100%	0%	0.91
kNN - clinical	100%	0%	100%	100%	0%	1.0
NB - clinical	83%	17%	83%	100%	0%	0.91

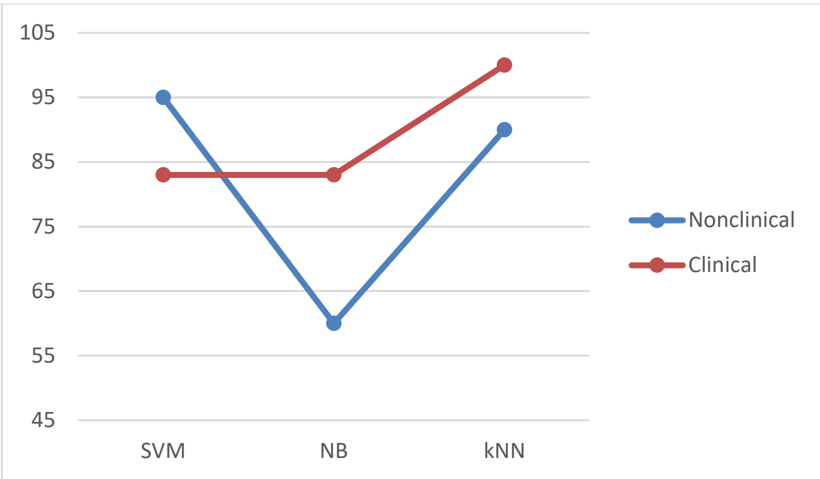


Figure 4. *Comparison of classifier results.*

4. CONCLUSIONS

Our study aimed to develop classifiers that could be used to develop an adaptive Virtual Environment Grocery Store platform. Participants carried out tasks at different levels in the non-adaptive VEGS platform, with some users finding tasks simpler or harder to complete. Using machine learning classifiers, we aim to adapt the VEGS to permit the platform to better detect the participants' performance in real time and determine their skill level. VEGS can utilize machine learning to enhance the overall experience of the user by providing personalized assessment and training of users. An important aspect of this study is that it identified metrics that may be utilized as inputs for machine learning algorithms and employed in future iterations of the VEGS (e.g., an adaptive VEGS). Moreover, this adaptative VEGS platform has facility for clinical applications.

Utilizing Support Vector Machine (SVM), Naïve Bayes (NB), and k-Nearest Neighbor (kNN), this study aimed to identify which algorithm would be best for determining when VEGS should adapt for a user. The study looked at 20 predictor variables captured while participants completed tasks within VEGS. In the nonclinical population it was observed that the SVM classifier achieved a correct classification rate of 95%. When introducing a population that has been diagnosed with epilepsy, the kNN algorithm was able to achieve a correct classification rate of 100%. It should be noted that this study had a limited number of participants (n=6) with epilepsy. This limitation should be address in future studies by including more participants with epilepsy to further verify our results. The results of the study revealed that the classifiers are capable of classifying individuals with epilepsy into the correct category. Knowing if a participant falls into a low performing category will help determine if the VEGS should adapt to personalize the environment relative to the participant's capacity for performing activities of daily living.

5. REFERENCES

Bohil, C. J., Alicea, B., & Biocca, F. A. (2011). Virtual reality in neuroscience research and therapy. Nature reviews neuroscience, 12(12), 752-762.

Bouman, Z., Elhorst, D., Hendriks, M. P., Kessels, R. P., & Aldenkamp, A. P. (2016). Clinical utility of the Wechsler Memory Scale—Fourth Edition (WMS-IV) in patients with intractable temporal lobe epilepsy. Epilepsy & Behavior, 55, 178-182.

Helmstaedter, C., & Elger, C. E. (2009). Chronic temporal lobe epilepsy: a neurodevelopmental or progressively dementing disease?. Brain, 132, 2822-2830.

Kennedy, R. S., Fowlkes, J. E., Berbaum, K. S., & Lilienthal, M. G. (1992). Use of a motion sickness history questionnaire for prediction of simulator sickness. Aviation, Space, and Environmental Medicine, 63(7), 588-593.

Kothgassner, O. D., & Felnhofer, A. (2020). Does virtual reality help to cut the Gordian knot between ecological validity and experimental control?. Annals of the International Communication Association, 44(3), 210-218.

Parsons, T. D. (2015). Virtual reality for enhanced ecological validity and experimental control in the clinical, affective and social neurosciences. Frontiers in human neuroscience, 9, 660.

Parsons, T.D., & Barnett, M. (2017). Validity of a Newly Developed Measure of Memory: Feasibility Study of the Virtual Environment Grocery Store. Journal of Alzheimer's Disease, 59, 1227-1235.

Parsons, T.D., & McMahan, T. (2017). An Initial Validation of the Virtual Environment Grocery Store. Journal of Neuroscience Methods, 291, 13-19

Assessing the Usability of Current Generation Virtual Reality in Adults with Intellectual Disabilities

Matthew C Harris[1], James Lewis[2], David J Brown[2], Pratik Vyas[2]

[1,2]Computing and Technology team, School of Science and Technology, Nottingham Trent University
Clifton Campus, Clifton Lane, Nottingham, NG11 8NS, United Kingdom

[1]*matthew.harris@ntu.ac.uk*

[1,2] *www.ntu.ac.uk*

ABSTRACT

Virtual Reality (VR) has shown to be an effective intervention for students with intellectual disabilities to improve skills for independent living, enhancing cognitive performance and improving social skills. However, these demonstrated benefits were mostly in the context of desktop (non-immersive), rather than headset-based VR.

A recent systematic review of VR as a support tool for the treatment of people with intellectual and multiple disabilities found that out of 28 studies only 3 used immersive VR technologies, and only 1 of those used platforms released within the last 10 years. One of the reasons for this lack of research may have been because the immersive VR used was wired technology, limiting movement of subjects being studied, as well as the large expense associated with VR in the past. However, current generation VR devices are ubiquitous, and do not require expensive, powerful hardware to drive them. The Oculus Quest is a consumer grade example, a self-contained VR headset that does not need an external computer to drive it. It comes with two 6 Degrees of Freedom (DOF) tracked controllers that are used to interact with virtual objects. It is wireless and has cameras which help in user being aware of their surroundings, making it safe and convenient for research. Thus, aim of this research is:

Aim: To evaluate the usability of the Oculus Quest for use by adults with intellectual disabilities.

Methodology: A protocol to assess participants' ability to use the Oculus Quest VR headset was based on an earlier study and extended here. The type of assistance (physical or verbal) required to progress through an introductory VR activity ('First Steps') was recorded. The headset display was also cast to a TV monitor to allow researchers to give assistance to participants, which was also recorded. In the first data collection stage, 9 adults aged 25-45 years with severe intellectual disabilities (including Down's syndrome and William's syndrome) were invited to independently attempt to complete the 'First Steps' activity. Any assistance given was categorised using the protocol. A post immersion follow-up focus group was held to record any qualitative feedback which might be useful. Observations (e.g., physiological responses) were also record.

Conclusions: Participants' ability to progress through the 'First Steps' activity varied. All participants received physical assistance in fitting the headsets, and controllers. 4 participants were able to complete the entire activity with only minor further verbal prompts, 1 with major physical assistance, and 4 did not complete the activity, due to issues using the Oculus Touch controller. The final participant that did not complete exhibited a physiological response. None of the other participants experienced these symptoms.

1. INTRODUCTION

Those with intellectual disabilities are often characterised as having significant limitations in intellectual functioning and adaptive behaviour. Using technological approaches to improve skills for independent living, enhancing cognitive performance, and improving social skills have been presented in past research (Standen and Brown 2005). However, relatively few studies have sought to use Virtual Reality to address these issues. One of the reasons for this lack of research may have been because immersive VR was wired technology, limiting movement of subjects being studied, as well as the large expense associated with VR in the past.

"Current generation Virtual Reality" is defined here as being any virtual reality platform released since 2014 as devices since this year marks a significant improvement in quality of experience over those released previously (*VIVE Specs & User Guide - VIVE Developer Resources*, 2016). Since 2016, current generation commercial virtual reality devices include the Oculus Rift and HTC Vive, with higher resolution and refresh rate able to produce a smoother and more convincing image, with less chance of motion sickness. One drawback of both the Oculus Rift and the HTC Vive is the necessity for the headsets to be tethered to a high-performance computer. The cost of the headsets, computer, as well as the space needed to set up the "base stations" present a significant barrier to use.

The Oculus Quest (2019) seeks to address these barriers by being entirely self-contained, incorporating its own power supply, storage and processing capabilities. It also features inside-out tracking meaning external hardware is not required for the headset or controllers to be tracked, and it is completely wireless. This, as well as its relatively low cost make it far more accessible to a wider range of users. So far, no study has addressed the potential of using current generation immersive virtual reality with those with an intellectual disability. The Oculus Quest has the potential to be an effective platform for this group due its relatively low cost, ease of set up and accessibility.

2. RELATED WORK

A recent systematic review on the use of Virtual Reality as a support tool for the treatment of people with intellectual and multiple disabilities found that out of 28 studies, only 3 used "immersive" Virtual Reality (Cunha, Neiva and Silva, 2018). Immersive virtual reality often makes use of a headset and other virtual reality devices as opposed non-immersive virtual reality, using a normal desktop or laptop computer to interact with a 3D environment. While this systematic review shows that non-immersive VR can be effective in some applications, immersive VR gives the user a greater sense of presence (Servotte *et al.*, 2020).

A study in 2016 combined brain computer interfaces and virtual reality as a training tool for participants with social attention disorders (Amaral *et al.*, 2017). This study used the Oculus Rift DK2 headset and compared the effectiveness of three separate BCI systems, showing it was feasible for use with participants with autistic spectrum disorders (ASD). No significant issues were reported in use with the four participants with ASD, showing that the use of VR is feasible for this group.

During a study in 2002, a protocol was developed to categorise the type of help needed by adults with learning disabilities to use virtual environments (Standen *et al.*, 2002). This study classified tutors' helping behaviour into 5 categories, including Specific Information, Non-specific Information, Gesture (including pointing at the screen), Touching Controls (involving physical assistance, e.g. putting their hand over the learners hand and moving the mouse) and Feedback (positive or negative). The amount of assistance offered over time decreased, however the goal achievement of the participants remained the same, this shows that adults with learning difficulties are capable of learning how to complete goals in VR.

A more recent paper using the HTC Vive Pro (a more recently released headset than the above mentioned Rift DK2 with higher resolution displays) invited students with mild-moderate intellectual disabilities to play Beat Saber, while a teacher assessed the student's experience and behaviour (Kongsilp and Komuro, 2019). Beat Saber is a rhythm game in which the user must slice incoming blocks representing musical beats, and as such was likely to have been beyond the coordination skills of some of the participants. It is also reported that some participants reported they could see the images clearly when they likely could not. The paper is brief, and the methodology is somewhat unclear however, it is reported that the participants engaged well with the activity.

A noted drawback of these studies is a lack of focus on the independent use of this system.

3. AIMS

The aim of this study is to evaluate the usability of the Oculus Quest for use by adults with ID. The level of support the participants required to use this device was assessed using an adapted version of an existing protocol (Standen *et al.*, 2002), and to inform future VR development.

4. METHODS

The study was divided into two parts: in the first, participants try an introductory tutorial application on the Oculus Quest, with the level of assistance recorded. In the second, the participants use the skills they have learnt previously in a subsequent less structured application. Following these, a focus group was held to gather semi-structured qualitative feedback.

4.1. Participants

Participants (N=9) consisted of adults with ID. Of these, 4 have Down syndrome, 2 have Williams syndrome, and 3 have moderate to severe learning difficulties. 6 were male, and 3 female. 2 participants were known to be familiar with (and regularly used) games consoles. Participation in the study was voluntary, and participants received an introductory talk on the headset and the study aims. Usability study guidelines have found that only 5 users are necessary to identify 85% of the usability problems in a system (Nielson and Landauer, 1993). Ethical approval for the study was granted by NTUs' non-invasive ethics committee.

4.2. "First Steps"

For the first part of the study, the participants were introduced to the Oculus Quest headset and controller as a group. Participants were then invited to try the "first steps" application with a facilitator to help where needed.

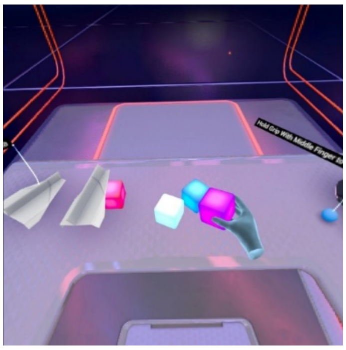


Figure 1: Screenshot from first steps

"First steps" is an introductory application on the Oculus Quest which teaches the user how to use the controller and headset to interact with their virtual surroundings(*First Steps on Oculus Quest | Oculus*, 2019). The participants are taught the function of each button through integrated prompts which signpost possible interactions. They are also taught how to perform specific gestures such as pointing and grabbing. Shortly following this they are presented with a range of objects such as paper aeroplanes, a bat and ball and rockets with which to practice these gestures. When they have completed this, they can apply what they have learnt in completing a dancing minigame. This activity takes in total about 15 minutes and is linear in nature.

Each participant was advised they could ask for help if they were stuck but were asked to complete the activity independently where possible. This was done in order to assess the feasibility of potential future interventions that might have the individuals using their VR devices from home without help.

Each participant was assisted by one dedicated facilitator who was experienced in using virtual reality and had completed "first steps" multiple times. The facilitators were asked to only give assistance if it was asked for, or if the participant had spent an excessive amount of time on one task. Live video casting was set up on a nearby monitor so facilitators could see what was being displayed on the headset and help the participants appropriately when asked for it. The facilitators were responsible for recording the level of assistance needed by each participant, using the framework described below.

4.3. Coding Framework

To assess how much help was needed, 3 levels of assistance were defined for each stage of the "first steps" application for each of 5 categories of help as described in Standen et al, (2002). These were:

1. An open verbal prompt: The participant is given a hint, rather than instruction.
2. A closed instructions: The participant would be directly told what to do (i.e. press button X, look over to the right)
3. Physical assistance: The participant would be given physical assistance in moving the controller or pressing the button.

For each step of the "first steps" application a form of words was devised for levels 1 and 2, and an assistance instruction was defined for level 3 to ensure consistency of assistance between those helping (see table 1)

Step	Task Description	Assistance						Completed for the participant
		Level 1	☑	Level 2	☑	Level 3	☑	☑
9	Glowing buttons with thumbs	“Look carefully at the controllers”		“Press the glowing buttons”		Physically help the participant find the controls		
10	Thumb sticks move around	“What are you being shown?”		“Move the control stick in your hands in a circle with your thumb”				

As can be seen above, if the participant was struggling with pressing the buttons on the controller, they would first be told to look carefully at the controllers, then if they were still observed to be having difficulties, would be told to press the glowing buttons. Finally, they would be given physical assistance in finding the buttons (potentially by guiding their thumbs to the right buttons). Alternatively, it was sometimes necessary to complete the task for the participant. The next level of assistance was given either when the participant asked for it, or when they had spent too much time on a task. The level of assistance given was recorded to assess how easily they were able to complete each step. Observation data were also recorded.

First Contact

After the participants completed the “first steps”, they were given a break, followed by the opportunity to try the “first contact” application. First contact is another introductory application released in 2016 with the Oculus Rift and has since been ported to the Oculus Quest. This is also designed to introduce the user to the Oculus touch controllers, but does so in a more sandbox, less constrained, explorable 3D environment, with no instructions or feedback given to the user. Participants were presented with objects that they could pick up and use and was therefore heavily reliant on the participant being able to apply what they had learnt in the previous activity. Participants were encouraged to complete as much of this activity as they can on their own. The protocol described previously was not used for this application, as the focus of this part was to gather qualitative feedback.

4.4. Group Based Discussion

The “First contact” activity was used as the basis for a group-based discussion on the usability of the Oculus Quest headset, controllers, and software. This discussion was recorded asking the following questions:

1. Did you enjoy using the device? What would you rate it out of 10?
2. Which was your favourite out of the two VR experiences you tried?
3. How easy did you find the device and the controllers to use?
4. Did you feel as though you needed the support of a technical person to use the device?
    a. Did you need much help using the headset?
    b. Did you feel confident using the device?
5. Do you think you could see yourself using the system daily/weekly? Why/Why not?
6. How “real” did the tasks you had to perform feel? How natural did picking up objects feel?
7. Did you experience any discomfort whilst using the device? Did your head feel dizzy/hot/sweaty when using the device?
8. Did you experience and problems using the device, like not being able to see or having trouble with the controllers?
9. Did you understand what you were supposed to be doing?

The people running the discussion were experienced in working with people with ID and the meaning of the words was explained for participants that required it.

5. RESULTS

5.1 Participants

5 (out of 9) participants were able to get to the end of the First Steps activity. All participants were able to get over halfway through with varying degrees of assistance. Reasons for not completing were mostly due to feeling tired, with one participant also exhibiting a physiological response. Those that didn't finish also tended to have more trouble with the controls, so spent more time in the activity.

All participants needed help fitting the headsets and adjusting the straps. 4 participants completed the activity with only minor prompts and one instance of physical assistance each. Of these, 3 had moderate to severe learning difficulties and one had Down syndrome.

Step	Task Description	Assistance								
		P1 (WS)	P2 (SLD)	P3 (DS)	P4 (DS)	P5 (DS)	P6 (DS)	P7 (SLD)	P8 (SLD)	P9 (WS)
		WS	SLD	DS	DS	DS	DS	SLD	SLD	WS
(throughout)	Guardian boundary	0	0	0	0	0	0	0	0	3
1	Straps	3	2	3	3	3	3	2	1	3
2	Position	3	2	3	3	3	3	1	2	3
5	Point + Click First steps	1	1	3	4	1	1	0	0	3
6	Footsteps 1	1	0	2	3	2	1	0	0	0
7	Footsteps 2	0	0	2	3	2	1	0	0	0
8	Footsteps 3 /Look at screen	0	0	2	3	0	0	0	0	0
9	Glowing buttons with thumbs	2	0	3	3	3	1	3	3	3
10	Thumb sticks move around	0	2	3	3	3	1	0	0	0
11	Click Thumb sticks	3	0	3	3	3	1	0	0	0
12	Trigger	0	0	3	3	3	1	0	0	1
13	Grip Button	3	0	3	3	3	2	1	0	2
14	Grip for Fist	0	0	3	3	3	1	1	1	2
15	Finger to point	0	0	3	3	3	1	1	1	1
16	Press button	1	0	3	3	3	2	2	0	2
17	Pick up and drop block	1	0	3	3	3	2	2	0	2
18	Options open up	Took headset off	0	3	3	4	0	0	1	Gave up
19	Bat and Ball		0	0	4	1	1	0	0	
20	Rockets		0	4	4	1	1	0	0	
21	Airship		0	4	4	1	1	0	0	
22	Swinging ball		0	0	4	1	1	0	0	
24	Console and Cartridges		0	3	4	Felt tired	1	1	1	
25	Insert all 4 plugs		2	4	4		0	1	0	
26	Shake to dance		0	0	had difficulty with controllers		1	0	2	
27	Dance?		0	0			0	0	0	
28	Dance again		0	0			0	0	0	
29	Eject Cartridge		0	0			1	1	1	

Key:	
No assistance needed:	0
Open Verbal prompt:	1
Closed Instruction:	2
Physical assistance:	3
Completed for them:	4
Did not complete:	

Figure 2 Table of how much assistance each participant needed

Participant 1 (Williams syndrome) did not complete the tutorial as they experienced discomfort (they reported that their head felt hot and they felt dizzy). This could have been a sign of motion or VR sickness, or alternatively a sign of physiological stress due to performance anxiety. The volume was muted for the first part of the activity so they could not hear the audio instructions, this may have contributed to the task stress. This was the only participant that exhibited signs of discomfort. They needed some physical assistance for some tasks.

Participant 2 (severe learning disabilities) had very little trouble in completing the activity. Only minor verbal assistance was needed. This participant has experience with games consoles so found the controllers easy to use.

Participant 3 (Down syndrome) needed quite a lot of physical assistance. They walked around the environment very slowly and did not seem comfortable in the virtual environment (despite later reporting that they enjoyed it). They also did not seem to be able to see the virtual objects in front of them very clearly. This is reinforced by the findings of Kongslip and Komuro (2019). The facilitator reported that they did not seem to understand some of the tasks and did not seem to realise when the headset was not on properly. They did not finish the activity, and had some tasks completed for them.

Participant 4 (Down syndrome) did not finish the activity and had a lot of difficulty using the controllers. They had some tasks completed for them and needed a lot of physical assistance. The facilitator reported that this participant did not seem to understand some of the tasks and got tired before the end.

Participant 5 (Down syndrome) needed a lot of physical assistance at the start but appeared to improve in performance as the experiment progressed. They did not finish the activity due to feeling tired. The facilitator reported that the participant understood what they had to do, but had difficulty using the controllers due to having small hands.

Participant 6 (Down syndrome) needed open verbal prompts and direct instructions for quite a few of the tasks, but besides this needed no physical assistance once the headset was fitted. Completed the activity.

Participant 7 (Severe learning difficulties) also needed open verbal prompts for some of the tasks, and one instance of physical assistance. Completed the activity with very little trouble.

Participant 8 (Moderate to severe learning difficulties) completed the activity with similar results to the previous two. Only needed physical assistance once (on pressing the buttons on the controllers, which most struggled with).

Participant 9 (Williams syndrome) got most of the way through with limited physical assistance. However, difficulty in using the controllers made picking up virtual objects difficult. Was the only participant that did not seem to respect the boundary system on the quest that notifies the user if they are in danger of bumping into a real-world object. The facilitator reported that with a great deal of concentration they were able to pick up a block but did not complete the activity as they found the controls too difficult to use.

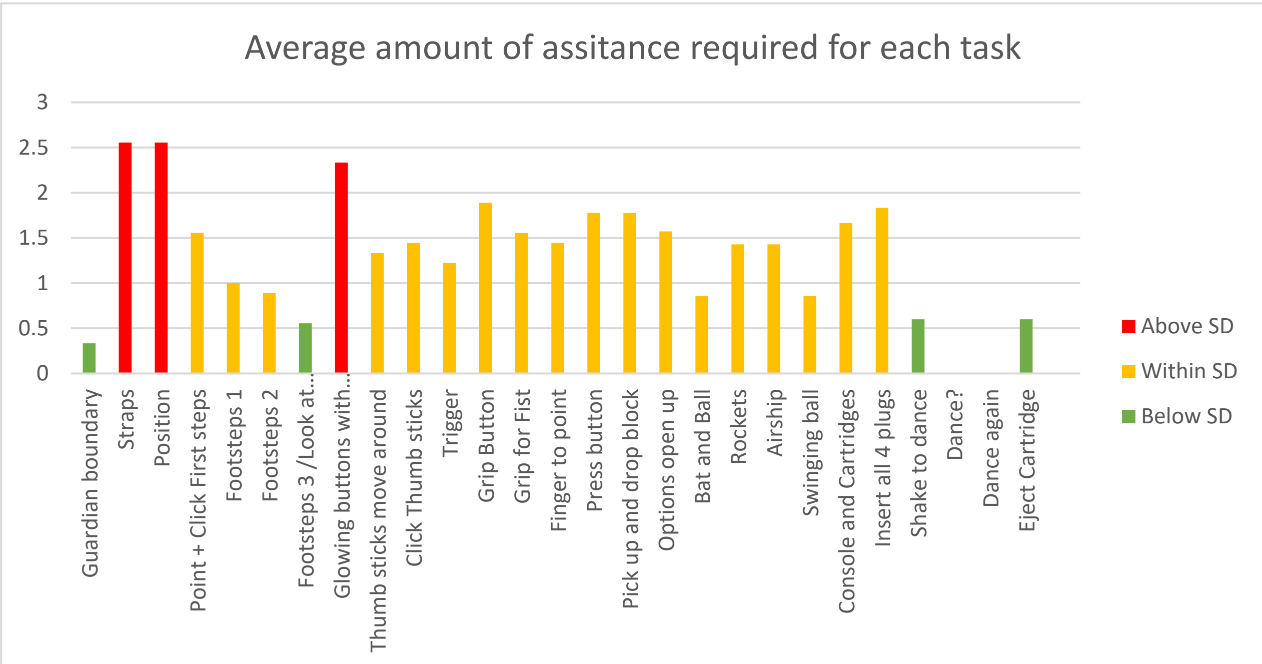


Figure 3 Average level of assistance needed for each activity in relation to standard deviaton

This data does not identify problems that are specific to those with ID, it's possible that a neurotypical group would have similar problems. To better assess this data, it will need to be compared with results from neuro-typical individuals, as those not familiar with the controllers may have similar problems. Those with Down syndrome needed the most assistance, followed by those with Williams syndrome, and those with severe learning difficulties needed the least assistance. All participants were given assistance in fitting the headset. Besides this, the task that most participants struggled with was orienting themselves correctly when asked to move to a specific location.

6. DISCUSSION & ANALYSIS

6.1. Fitting the headset

The participants were all given physical assistance in fitting their headsets by their facilitators (hence why the scores for straps and position are so high). However, it was difficult for the facilitators to tell whether the headset was on properly, as they were reliant on feedback from the participants on what they could see in front of them. In one case, it became clear that the headset may have not been on correctly some way into the activity. Some participants also had smaller heads (especially those with Down syndrome), making the headsets more difficult to fit.

6.2. Moving around in virtual space

One of the first things the user must do upon loading "first steps" is move over to the virtual footprints that appear on the ground in front of them. Only one participant seemed unstable in walking over to these footprints, but all except for one seemed to understand that walking around in real space corresponded to them moving through virtual space.

6.3. Pressing the buttons and triggers

6 out of 9 participants needed physical assistance in finding the buttons and triggers on the Oculus Touch controllers. "First steps" prompts the user with virtual versions of their controllers and makes the button the user needs to press glow. However, the user is unable to see their hands as they are obscured by the headset. The participants were not introduced to the controller before putting the headset on, meaning they would have had to figure out where the buttons were, while immersed. Had they been shown the controllers before putting the headset on they may have been more successful.

6.4. Using the controllers to perform gestures

In order to interact with virtual objects, the user is required to perform specific gestures using the grip and trigger buttons (on the back of the controller). For example, to point, the user must hold the grip button and not be pressing (or have their finger resting on) the trigger button. Some participants found this level of dexterity too difficult to perform, and frequently left their fingers resting on the trigger button. It was also noted that some that struggled with this initially were able to learn the gestures and perform them successfully later.

Figure 4 Oculus Quest controllers

6.5. Using gestures to interact with objects

A user is able to pick up and object if a grip gesture is performed while their hand is positioned over an object. Some participants seemed to struggle with the depth perception and frequently attempted to perform the gesture when their hands were not near enough to the object. All participants were able to pick up a cube with assistance.

6.6. Focus group feedback

The focus group was held 5 weeks after the initial data-collection event due to time constraints. Immediately prior to this, 3 participants were given the opportunity to try "first contact" for the second time. All participants indicated that with enough practice they would be able to use the device unassisted, although one participant mentioned that they would need more support in using the controllers. Another participant mentioned that they felt discomfort whilst wearing the headset and indicated that this came from the weight of the headset.

7. CONCLUSIONS

Though based on a small sample, the results so far seem to support the idea that individuals with different disabilities need different levels of assistance using Virtual Reality. Much of the data seems to support the hypothesis that adults with intellectual difficulties can use the Oculus Quest, with some showing promise of being able to use it independently after a short learning period, and others requiring more practice. There are some issues that need to be considered when developing interventions.

7.1. Recommendations:

1. Keep the use of the buttons to a minimum: The button layout of the Oculus Quest controllers (and many Virtual reality controllers in general) are unfamiliar to most users. The grip button especially seems to be problematic for many, and therefore may require more time for a new user to get used to.
2. Avoid complex gestures where possible: Almost all the participants in this study were able to pick up an object using the grip gesture given enough time. This is likely to be necessary in many VR applications. However, teaching gestures more complex than this may not be feasible.

The Oculus Quest controllers will be unlike any device used before for many users. Ensuring participants are familiar with the layout of the controllers and have been introduced to the various buttons before using them for the first time in VR may be a useful strategy for future study design.

7.2. Coordination constraints

Some participants understood what they had to do but were unable to do it due to poor cognition and/or coordination. Other participants did not seem to comprehend what they had to do. For those with limited by coordination, it may be more effective to develop applications that only use the headset, and do not require use of the controllers.

7.3. Engagement and enjoyment

During the focus group, the participants stated that they enjoyed the activity. The facilitators also reported that all participants were immersed and engaged within the activity.

8. REFERENCES

Amaral, C. P. *et al.* (2017) 'A novel Brain Computer Interface for classification of social joint attention in autism and comparison of 3 experimental setups: A feasibility study', *Journal of Neuroscience Methods*. Elsevier B.V., 290, pp. 105–115. doi: 10.1016/j.jneumeth.2017.07.029.

Cunha, R. D. da, Neiva, F. W. and Silva, R. L. de S. da (2018) 'Virtual Reality as a Support Tool for the Treatment of People with Intellectual and Multiple Disabilities: A Systematic Literature Review', *Revista de Informática Teórica e Aplicada*, 25(1), p. 67. doi: 10.22456/2175-2745.77994.

First Steps on Oculus Quest | Oculus (2019). Available at: https://www.oculus.com/experiences/quest/1863547050392688/?locale=en_GB (Accessed: 4 May 2020).

Kongsilp, S. and Komuro, T. (2019) 'An evaluation of head-mounted virtual reality for special education from the teachers' perspective', in *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*. New York, NY, USA: Association for Computing Machinery, pp. 1–2. doi: 10.1145/3359996.3364721.

Nielson, J. and Landauer, J. (1993) 'A mathematical model of finding the usability problem. Proceedings of the CHI 93 proceedings of the Interact conference on human factors in computing systems', *Espacio de Trabajo Matemático. Quinto Simposio Internacional ET*. New York, New York, USA: Publ by ACM, pp. 206–213. doi: 10.1145/169059.169166.

Servotte, J. C. *et al.* (2020) 'Virtual Reality Experience: Immersion, Sense of Presence, and Cybersickness', *Clinical Simulation in Nursing*. Elsevier Inc., 38, pp. 35–43. doi: 10.1016/j.ecns.2019.09.006.

Standen, P. J. *et al.* (2002) 'How tutors assist adults with learning disabilities to use virtual environments', *Disability and Rehabilitation*. Taylor & Francis, 24(11–12), pp. 570–577. doi: 10.1080/096382802320179244.

Standen, P. J. and Brown, D. J. (2005) 'Virtual Reality in the Rehabilitation of People with Intellectual Disabilities: Review', *CyberPsychology & Behavior*, 8(3), pp. 272–282. doi: 10.1089/cpb.2005.8.272.

VIVE Specs & User Guide - VIVE Developer Resources (2016). Available at: https://developer.vive.com/resources/knowledgebase/vive-specs/ (Accessed: 12 June 2020).

Clinical feasibility of the immersive Virtual Memory Task in patients with prodromal Alzheimer's Disease

S Krohn[1], S Rekers[2], H Megges[3], SD Freiesleben[4], J Belger[5], EM Quinque[6], M Blume[7], J Tromp[8], F Klotzsche[9], L Kämmer[10], S Kray-Niemczyk[11], P Chojecki[12], A Thöne-Otto[13], M Gaebler[14], O Peters[15], C Finke[16]

[1,2,10,11,16]Department of Neurology, Charité-Universitätsmedizin Berlin, Berlin, GERMANY

[1,2,8,9,10,11,14,16]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Berlin, GERMANY

[3,4,15]Department of Psychiatry, Charité –Universitätsmedizin Berlin, Berlin, GERMANY

[3,4,15]Memory Clinic and Dementia Prevention Center, Experimental and Clinical Research Center (ECRC), Berlin, GERMANY

[5,6,7,13]Clinic for Cognitive Neurology, University Hospital Leipzig, Leipzig, GERMANY

[5,6,7,8,9,14]Max-Planck Institute for Human Cognitive and Brain Sciences, Leipzig, GERMANY

[12]Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Berlin, GERMANY

[1]*stephan.krohn@charite.de*, [2]*sophia.rekers@charite.de*, [3]*herlind.megges@charite.de,* [4]*silka-dawn.freiesleben@charite.de,* [5]*Julia.Belger@medizin.uni-leipzig.de,* [6]*Eva.Quinque@medizin.uni-leipzig.de,*

[7]*Marie.Blume@medizin.uni-leipzig.de,* [8]*tromp@cbs.mpg.de,* [9]*klotzsche@cbs.mpg.de,* [10]*luca.kaemmer@charite.de,*[11]*sophie.kray-niemczyk@charite.de,* [12]*paul.chojecki@hhi.fraunhofer.de,* [13]*Angelika.Thoene-Otto2@medizin.uni-leipzig.de,* [14]*gaebler@cbs.mpg.de,* [15]*oliver.peters@charite.de,* [16]*carsten.finke@charite.de*

[1,2,10,11,16]*www.cognitive-neurology.com,* [1,2,8,9,10,11,14,16]*www.mind-and-brain.de,* [3,4,15]*https://psychiatrie.charite.de,* [3,4,15]*www.mdc-berlin.de/ecrc,* [5,6,7,13]*www.uniklinikum-leipzig.de/einrichtungen/tagesklinik-neurologie,* [5,6,7,8,9,14]*www.cbs.mpg.de/departments/neurology,* [12]*www.hhi.fraunhofer.de*

ABSTRACT

Deficits in spatial cognition are a common manifestation of prodromal Alzheimer's Disease (pAD). Immersive Virtual Reality (VR) holds great potential to improve the assessment of spatial cognition, yet VR-induced adverse effects may limit clinical feasibility. Here, we study the safety profile of a novel VR paradigm for the assessment of spatial memory, the immersive Virtual Memory Task (imVMT). Kinetosis symptoms before and after exposure to the imVMT were measured with the Simulator Sickness Questionnaire (SSQ) in 15 patients with pAD and 21 cognitively healthy older adults. SSQ ratings showed excellent feasibility in both patients and controls, with very limited occurrence of kinetosis symptoms overall and no significant increase in symptoms after VR exposure. These findings support the clinical feasibility of the imVMT in patients with pAD and suggest that adverse effects are unlikely to confound task performance.

1. INTRODUCTION

Impairment of spatial cognition has been proposed as a sensitive marker of prodromal Alzheimer's Disease (pAD) (Coughlan et al., 2018), and digital diagnostics show high potential to detect such early cognitive deficits in patients with pAD (Öhman et al., 2021). Immersive Virtual Reality (VR) allows for the assessment of spatial abilities in ecologically relevant, yet well-controlled environments (Krohn et al., 2020), while maintaining spatial depth perception through stereoscopic vision. However, as exposure to this technology can result in VR-related adverse effects, an important clinical prerequisite consists in a satisfactory safety profile of new VR applications. Here, we examine the occurrence of adverse effects in the immersive Virtual Memory Task (imVMT), a novel VR paradigm to assess visuospatial memory in a virtual household setting (Belger et al., 2019; Krohn et al., 2020).

2. METHODS

The imVMT was administered to patients with mild cognitive impairment (MCI) due to AD. Patients were recruited from the Memory Clinic of Charité-Universitätsmedizin Berlin (n=15; median age 76 years [range: 66-87]; 9 female; mean Montreal Cognitive Assessment score 21.3±2.9 [range 16-26]; post-exposure ratings available for 13 patients). AD as the neurobiological basis for MCI was classified based on amyloid and tau status, following the A/T/N classification (Jack et al., 2016). Cognitively unimpaired older adults were included as control participants (HC; n=21; median age 71 [65-85]; 15 female). Participants rated the presence of kinetosis symptoms (ordinal scale: none, slight, moderate, severe) before and after VR exposure with the Simulator Sickness Questionnaire (SSQ; 16 items evaluating nausea, oculomotor, and disorientation symptoms) (Kennedy et al., 1993). Total VR exposure amounted to approximately 1.5 hours.

3. RESULTS

Cybersickness symptoms were very limited overall, and severe adverse effects were absent in both groups. Difficulty concentrating and visual symptoms represented the most prevalent symptoms, while vertigo-related and gastrointestinal symptoms were largely absent. Non-parametric analysis of pre-exposure vs. post-exposure ratings showed that there was no significant increase of kinetosis symptoms after VR exposure.

4. CONCLUSION

Despite comparatively prolonged VR exposure, the imVMT shows an excellent adverse effects profile in both patients with pAD and cognitively unimpaired older adults. These findings support the clinical feasibility of the paradigm in patients with pAD and suggest that adverse effects are unlikely to confound task performance.

5. REFERENCES

Belger, J, Thoene-Otto, A, Krohn, S, Finke, C, Tromp, J, Klotzsche, F, Villringer, A, Gaebler, M, Chojecki, P, and Quinque, E, (2019), Immersive Virtual Reality for the Assessment and Training of Spatial Memory: Feasibility in Individuals with Brain Injury, *2019 International Conference on Virtual Rehabilitation (ICVR)*, Tel Aviv, 1–2.

Coughlan, G, Laczó, J, Hort, J, Minihane, AM, and Hornberger, M, (2018), Spatial navigation deficits—Overlooked cognitive marker for preclinical Alzheimer disease?, *Nature Reviews Neurology*, *14*(8), 496–506.

Jack, CR, Bennett, DA, Blennow, K, Carrillo, MC, Feldman, HH, Frisoni, GB, Hampel, H, Jagust, WJ, Johnson, KA, Knopman, DS, Petersen, RC, Scheltens, P, Sperling, RA, and Dubois, B, (2016), A/T/N: An unbiased descriptive classification scheme for Alzheimer disease biomarkers, *Neurology*, *87*(5), 539–547.

Kennedy, RS, Lane, NE, Berbaum, KS, and Lilienthal, MG, (1993), Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness, *The International Journal of Aviation Psychology*, *3*(3), 203–220.

Krohn, S, Tromp, J, Quinque, EM, Belger, J, Klotzsche, F, Rekers, S, Chojecki, P, de Mooij, J, Akbal, M, McCall, CA, Villringer, A, Gaebler, M, Finke, C, and Thoene-Otto, A, (2020), Multidimensional evaluation of Virtual Reality paradigms in clinical neuropsychology: The VR-Check framework, *J Med Internet Res, 22(4):e16724*.

Öhman, F, Hassenstab, J, Berron, D, Schöll, M, and Papp, KV, (2021), Current advances in digital cognitive assessment for preclinical Alzheimer's disease, *Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring*, *13*(1).

Systematic Literature Review: Technology-Based Interventions for Social Functioning Rehabilitation in Individuals with ABI

L-J Douch[1], M Keijsers[2], S Hoermann[3]

[1,2]Human Interface Technology Lab NZ, University of Canterbury,

69 Creyke road, Ilam, Christchurch, NEW ZEALAND

[2,3] School of Product Design, University of Canterbury,

9 Engineering Road, Ilam, Christchurch, NEW ZEALAND

[3]*simon.hoermann@canterbury.ac.nz*

[1,2,3]*https://www.canterbury.ac.nz*

ABSTRACT

Acquired brain injury (ABI) contributes to death and disability more than any other traumatic insult. Among other things it impairs social functioning, yet rehabilitation commonly disregards retraining social skills in favour of improving cognitive or physical functioning. This leaves individuals at an increased risk of becoming socially isolated which in turn contributes to the high rates of depression and anxiety among individuals with ABI.

Interactive technology could offer uncharted opportunities for providing individuals with ABI with personalised social functioning training. Several reviews have already been published evaluating interactive technology for ABI rehabilitation but these tend to focus on cognitive and physical functioning rather than social skills. The current review therefore focuses on interactive technology for social functioning rehabilitation following an ABI. The findings from 11 papers were evaluated and summarised. Technology based interventions were found to be generally well evaluated and effective. In particular teleconferencing was marked as promising, as it is more accessible than, for example Virtual Reality (VR). Limitations included low participant numbers and the pre-post test design in most studies, which reduced the statistical power and prevented inferences being made on the added benefit of the intervention over existing therapies.

1. INTRODUCTION

Acquired brain injury (ABI) is estimated to affect between 64 and 74 million people worldwide each year (Dewan et al., 2018), leaving between 150 and 200 per million with severe disabilities (Hopwood, Nanjing, Donnellan & Shiatsu, 2010). ABIs usually result in physical and cognitive impairments and as a consequence often interfere with social functioning (Intercollegiate Stroke Working Party, 2012). For example, as individuals may take longer to process information during a conversation, their response will be delayed and their ability to “keep up” with the conversation in a group setting is greatly reduced. Furthermore, as ABIs impact individuals’ behaviour management, they can respond inappropriately in a social setting which causes others to view them as rude or abrupt. These and other impairments can result in decreased social, physical, and cognitive functioning (the State of Queensland Health, 2018).

Individuals who suffer from ABI are commonly offered some form of rehabilitation therapy, with the aim to improve their physical or cognitive functioning. These kinds of therapies are both well researched and addressed in the literature and current best practise documentation, with several academic papers focussing on technology-based ABI interventions. These interventions aim to improve cognitive abilities such as memory, attention and orientation (Dores et al., 2012; Gamito et al., 2017; Sanchez et al., 2019), as well as physical abilities such as balance, mobility and motor skills (Cameirão, Badia, Oller, & Verschure, 2010; Kizony et al., 2014; Lloréns, Colomer-Font, Alcañiz, & Noé-Sebasián, 2013). However, the impaired social functioning resulting from ABIs is scantily addressed. While many of the interventions may indirectly assist in improving one’s social functioning, only a few studies explicitly address the issue of impaired social functioning. Social functioning is defined as the ability of a person to interact successfully with other people in various environments such as at work, during social activities and in relationships with partners, family and friends (Bosc, 2000). This social functioning depends on social skills, which are defined as the skills required to have successful social interactions, achieve one's goals, collaborate with others and control emotions (OECD, 2015). Deficits to these skills are a common result of ABI, compromising an individual's ability to maintain relationships and participate in social activities and eventually leading to a loss of relationships and friendships (McDonald, Togher, & Code, 1999). This deterioration of interpersonal relationships increases the risk of depression in individuals with ABI (Bhogal, Teasell, Foley, & Speechley, 2003).

The lack of interventions explicitly designed for supporting and improving social functioning is therefore both relevant and concerning. The current systematic literature review has been completed in support of a masters' research thesis, which follows the development of a design prototype for an interactive tool to rehabilitate social functioning in individuals with ABI. The primary focus of the current review is to provide an overview and evaluation of the technology-based interventions that are currently available for the rehabilitation of social functioning in individuals with ABI.

2. METHOD

2.1 Research questions

The research questions used to drive this review were as follows:

1. What technology-based interventions have been developed since 2009 to assist with the rehabilitation of social functioning in individuals with ABI?

2. What were the outcomes of these interventions in terms of improvement of social skills in individuals with ABI?

Any study describing a technology-based intervention to rehabilitate social functioning in individuals with ABI was included. Descriptions of outcome measures and outcomes within a piece of literature were considered. All literature published before 2009 were excluded from the review to ensure studies were current and relevant. See Section 2.3 for an exhaustive list of the inclusion and exclusion criteria.

2.2 Search process

The search strategy and medical subject headings were adjusted for each database by the primary researcher with assistance from a communication studies subject librarian at the University of Canterbury library. Examples of words used in the search strategy are: brain injuries, stroke, social behaviour, communication and serious or applied game. The search process included a manual search of eight databases accessed through the University of Canterbury library database: Cochrane Library, Embase, Medline, PsychINFO, clinicaltrials.gov, ANZCTR, Compendex (Indexes ACM + IEEE) and Scopus. In addition to searching these repositories, Google Scholar was searched to identify any relevant grey literature (e.g. unpublished work or theses). These searches were completed in January 2020, and repeated in May 2020 to ensure inclusion of any recently published studies.

2.3 Eligibility criteria

All types of studies – random controlled trials, quasi-experimental designs, single-group pre-post tests, case studies – were included in the review. The following inclusion criteria were observed: The paper describes an intervention for ABI's including stroke and TBI (Traumatic Brain Injury); the intervention must have a primary aim of improving social skills, social functioning or social participation; the intervention is technology-based: uses a form of technology; is published from 2009 onwards in English or a translated copy is available.

The exclusion criteria were as follows: the intervention focuses on physical or cognitive therapy rather than therapy for social functioning; the study population has co-morbidities; the intervention is used for diagnosis purposes rather than training/rehabilitation purposes; the intervention involves brain-machine/computer interfaces.

2.4 Data extraction

The following data was extracted from the final selection of literature: the full reference; the type of study and study methodology (for quality assessment); the type of ABI being addressed; a description of the technology-based intervention including what kind of technology is being used, how it is used and what it aims to do; the outcome of the study; conclusions and limitations of the research.

2.4 Scientific quality assessment

Three different tools for study quality assessment were obtained from the National Heart, Lung and Blood Institute (NHLBI, 2020) in order to systematically evaluate the quality of the selected literature. These quality assessment tools contain a set of items that target potential flaws in the study's methodology and implementation which may have introduced bias, confounding, power issues, causality problems and other forms of inaccuracy. Two independent researchers assessed the quality of each of the selected studies with the help of these tools. Any disagreements in the assessment were resolved through discussion.

For the effectiveness studies, usability studies, feasibility studies and pilot studies where there was no control group, the Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group was used. This assessment tool contains items such as "was the study population clearly specified and defined?" and "was a sample size justification, power description, or variance and effect estimates provided?".

For the randomised-controlled trials, the Quality Assessment Tool for Controlled Intervention Studies was used. This tool addresses questions such as "was the method of randomization adequate (i.e., use of randomly generated assignment)?" and "were study participants and providers blinded to treatment group assignment?".

Finally, for the cohort studies the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was used. This version of the quality assessment tool contains items along the lines of "were eligibility/selection criteria for the study population prespecified and clearly described?" and "were all eligible participants that met the prespecified entry criteria enrolled?"

2.5 Data analysis

NVivo was used to code the main themes in the selected papers, using the following nodes: *Description of the intervention*: outcomes of interest, methodology, type of technology used; *Study outcome*: efficacy, effectiveness, usability, feasibility or acceptability, and *Conclusions and limitations of the study*.

3. RESULTS

1,124 papers were identified through initial database searches; 33 from Cochrane, 765 from Embase, 222 from Medline, 95 from PsychINFO, 2 from clinicaltrials.org, 6 from Compendex, and 1 from Scopus. After removal of the duplicates, a set of 472 studies remained for title screening by the primary researcher; a random selection of fifty titles from this set was screened by the secondary researcher to ensure correct use of the inclusion/exclusion criteria and to validate the primary researcher's decisions. The title screening left 52 papers for abstract screening; this was done by both the primary researcher and the secondary researcher independently. 22 full texts were screened on the inclusion/exclusion criteria by the primary researcher. 11 of those were excluded from data extraction as they covered interventions that did not have the primary aim to improve social functioning in individuals (n = 6); focussed on video games as a means of assessment of social functioning, which made it a diagnosis rather than rehabilitation or training tool (n = 4); and were not technology-based (n = 1).

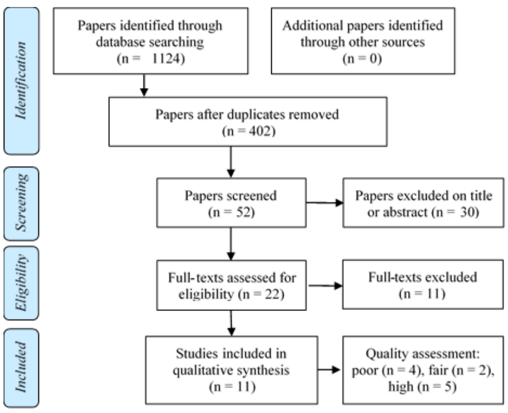


Figure 1. *Flow diagram of the study selection process*

The final selection of 11 full texts was assessed for quality by the primary researcher and a secondary researcher independently (see Section 2.5). Any disagreements between the reviewers were resolved through discussion. Furthermore, data was extracted and analysed for discussion by the primary researcher. See Figure 1 for a flow diagram of the selection process; see Table 1 for an overview of the selected papers and their quality assessment.

4. DISCUSSION

The selected studies describe a wide range of technology-based interventions including tablet-based interventions, Virtual Reality (VR)-based videogames, VR-multitouch technologies and videoconferencing (see Table 1). Four studies were determined to be of low quality (Janssen, Salaris, Quinn, Jordan, Galvin, & Vietch, 2016; Meltzer, Harvey, & Baird, 2015; Januth et al., 2016; Meulenbroek & Chemey, 2017) because they did not report on randomisation, blinding, group (dis)similarities, dropout rate, treatment adherence, or provide power assessment (Janssen et al., 2016; Meltzer et al., 2015); or because they had no control group, did not specify inclusion and exclusion criteria, report on representativeness of the participants, nor did they follow blinding or used multiple measurements to address the outcome of interest (Januth et al., 2016; Meulenbroek & Chemey, 2017). These four studies will be discussed first but have to be interpreted with care as they might be biased.

Janssen et al. (2016) investigated the potential of a tablet-based intervention to improve post-stroke quality of life, which was measured through various social skills. The intervention group received training to use tablets which they could take home after being discharged from inpatient care, while the control group received no intervention. One month after discharge participants' quality of life was assessed by means of an interview-administered set of self-report scales, covering areas such as self-care, work, personality and social roles (Hillari, Lamping, Smith, Northcott, Lamb, & Marshall, 2009). Quality of life was found to be higher for the intervention group but no improvements were found for secondary measures such as mood, cognition, or self-efficacy.

Meltzer et al. (2015) studied the effectiveness of teleconferencing for delivering post-stroke communication disorder therapy. Individuals who had suffered a stroke were assigned to either traditional face-to-face therapy or remote meetings via teleconferencing, both of which continued for 10 weeks. Both groups were given homework tasks to be completed on tablet devices. Individuals were assessed on their linguistic, cognitive and functional skills both before and after treatment. Similar results were obtained for both groups, suggesting that teleconferencing could be a viable alternative when in-person therapy is not possible.

Januth et al. (2016) developed a tablet application with language-based exercises that could be used for rehabilitation of speech and language skills. The interface included 520 exercises which were designed in collaboration with speech and language therapists. Participants in the study reported high acceptance of the app as well as high usability; but acquired skills were not measured nor was there a control group to benchmark against.

Finally, Meulenbroek et al. (2017) studied a computerised role play programme called WoRSTER, which trains appropriate word choices across different social contexts, such as informing, requesting, advising, and clarifying. It provides audio-visual feedback and practise opportunities for new skills. Participants were measured on their appropriate choice of words pre-treatment and post-treatment, and results showed an increased use of politeness markers in both practised and spontaneous speech.

The remaining seven studies (Hoover & Carney, 2014; Mallet et al, 2016; Pugliese et al., 2019; Rietdijk, Power, Brunner, & Togher, 2018; Gretchuta, Rubio, Duff, Oller, Pulvermüller, & Verschure, 2016; Kolk, Saard, Pertens, Kallakas, Sepp, & Kornet, 2019; Lloréns, Noé, Ferri, & Alcañiz, 2015) were determined to be of fair or good quality, making their findings more dependable. Hoover & Carney (2014) discussed three different ways to use an Apple iPad for the treatment of aphasia (language impairment): to support social interaction, to distribute personalised therapeutic exercises, and to remotely monitor the performance on those exercises. Patients used iPad to show and explain images to their communication partner in dyadic interactions, or for visual support and to cue speech output in group settings. In addition, a number of available apps were integrated into the therapy, like iTherapy/Constant Therapy, which allowed a therapist or health professional to assign various tasks as a part of cognition and language therapy, depending on the patient's individual needs. Finally, the therapist or health professional could monitor performance and update assignments remotely. Pre-/post use of iTherapy revealed significant improvements on a number of target measures, such as communicative independence, confidence and participation. Moreover, statistically significant improvements were recorded for measures on linguistic and functional performance as well as in quality of life (Hoover & Carney, 2014).

Table 1. *Overview of the studies, their interventions, and their assessed quality*

Reference	Intervention under study	Findings	Quality
Janssen et al., 2016	Effect of tablet use throughout rehabilitation.	Quality of life was better for the intervention group than the control group, but not on mood, cognition, communication, or self-efficacy.	Poor
Meltzer et al., 2015	TeleRehab for post-stroke communication disorders.	TeleRehab yielded similar improvements as in-person rehabilitation therapy.	Poor
Januth et al., 2016	Tablet-based rehabilitation of speech and language.	The application received high marks on usability from both healthy participants and TBI patients.	Poor
Meulenbroek et al., 2017	WoRCTER, a web-based social/professional communication training programme.	Participants' use of politeness markers in spoken text (e.g. would, could, maybe) increased post-intervention.	Poor
Hoover & Carney, 2014	Integration of tablets and therapy apps into rehabilitation.	Significant improvements from pre- to post-treatment on communication and quality of life measures.	Fair
Mallet et al., 2016	*RecoverNow*. Tablet-based and integrates therapy-based apps.	High in-hospital retention rate (97%), with most participants rating *RecoverNow* as at least moderately useful.	High
Pugliese et al., 2019	*RecoverNow*. Tablet-based and integrates therapy-based apps.	High daily-life retention rate (77%), but barriers included mismatch between app difficulty and patient skills.	High
Rietdijk et al., 2018	*TBIconneCT*. Therapy via videoconferencing.	Improvement in conversation skills post-intervention.	High
Grechuta et al., 2016	Videogame-based group therapy, table top touch surface.	Perceived improvements in language skills by both patient and therapist. High approval and acceptance ratings.	Fair
Kolk et al., 2019	VR and multi-touch technology applications.	Communication, metacognitive, coping skills improved.	High
Lloréns et al., 2015	VR-based rehabilitation gaming system.	Patient's awareness of their own deficits and their implications improved, as did social skills and behaviour. High usability ratings.	High

Two papers studied the feasibility of the RecoverNow intervention, a tablet-based app, which delivers speech and cognitive therapy to individuals who have had a stroke (Mallet et al., 2016; Pugliese et al., 2019). In both studies, participants got assigned tablet-based intervention apps by their therapists, specific to each individual's therapy needs. Apps focused on training stroke-induced deficits related to communication, cognition, and fine-motor ability. Being feasibility studies, retention and participation rates were measured rather than efficacy (Mallet et al., 2016; Pugliese et al., 2019). Mallet et al. reported an in-hospital retention rate of 97%, with one individual declining to continue as he found the technology challenging. 83% of the participants were able to spend the recommended one hour per day using RecoverNow (2016). Pugliese et al. (2019) reported less positive results with regards to tablet usage habits of both in-patient and out-patient participants. While RecoverNow was determined to be feasible, only 3 out of 30 participants completed the three-month trial of the intervention, and participants used RecoverNow only 50% of the days that they could have been engaging in therapy. These low adherence rates may be explained by the barriers that were identified by participants: a dislike of the app content, finding the app content too difficult to use, reported difficulties with focusing and reading, and language barriers.

Rietdijk et al. (2018) pilot tested the telehealth application TBIconneCT, which uses information- and communication technologies such as videoconferencing to deliver social communication training after TBI. It is an adaptation of TBI Express, an established program that is designed to practise and improve social interaction skills. The 10-week TBIconneCT program involves a weekly group session, a weekly individual session and home practice tasks. Within these sessions patients engage in structured role-plays, conversational practise and reviewing social interaction recordings to identify communication difficulties. Rietdijk et al. measured the impact of TBIconneCT on two participants' conversational skills, self- and other-report of communication skills, self-report of communication confidence, quality of life and social participation; as well as the overall feasibility (2018). No effect on conversational skills was found, possibly due to unstable baseline data. However, a positive change in communication skills was reported by both participants and their communication partners, and participants reported improved confidence in communication skills. Moreover, quality of life measures showed self-reported improvements in cognition, self, daily life, autonomy, and conversation skills. With regards to feasibility, both participants and their conversational partners reported the experience of telehealth as positive, communicating that it was “easy and they had no concerns about privacy or security issues” (Rietdijk et al., 2018, p. 101).

Grechuta et al. (2016) employed two participants to pilot test a VR-based gamified language rehabilitation tool for improving patient communication skills. In this tool, two participants are placed opposite one another in a shared ‘virtual room’ with a table with objects in between them. One of the participants selects an object from the table and must verbally request that object from the other player – the other player should understand the request and pass the correct object. If the social interaction is successful both players earn a point. Participants had their communication skills measured pre- and post-intervention, and completed a system evaluation questionnaire which asked their opinion on the intervention, its usability, functionality, and design (Grechuta et al., 2016). Improvements in communication skills were observed in both participants, and self-reported communication skills increased from pre- to post-intervention by 14.7% and 27.9% respectively. In addition, both participants evaluated the system and the intervention positively.

To enhance rehabilitation of socio-cognitive skills in children with ABI, Kolk et al. (2019) applied a combination of VR and multi-touch technology, which allows multiple people to interact with a touch surface simultaneously. Two multitouch-multiuser table top devices were used in the study: the Diamond Touch Table with the NoProblem! application, and a SnowflakeMT (Multi Touch) device. NoProblem! is an application that trains communication skills by providing tasks related to discussion and role playing for starting, continuing, changing, and ending conversations. SnowflakeMT trains executive functioning and cooperation skills by providing the user with a variety of educational tasks. For example, in one task children draw a picture together which trains cooperation skills, as it requires them to agree on the drawing, distribute tasks, and then name the picture together. In another task VR-metaphors are used to train social skills, anxiety coping mechanisms, and emotion perception. Another task still trains social attention and Theory of Mind abilities through displaying videos of different social scenarios such as bullying (Kolk et al., 2019). Kolk et al. (2019) report improvements on executive functioning, cooperation, negotiation and manual skills in a team environment as well as improvement in communication, language, metacognition and coping skills in social situations. Results also showed that both devices enabled participating children to acquire new communication and language skills and helped them to cope with difficult social situations. The use of video and VR training resulted in positive change in “intuitive and natural communication, social attention, emotional attitude, verbal skills, nonverbal and gestural behaviours, and decreased social anxiety” (Kolk et al., 2019, p. 330).

Lloréns et al. (2015) also discussed a tabletop touch surface intervention. Specifically, integrative videogame-based group therapy was used for improving self-awareness, social skills and behaviours in TBI patients. Participants are divided into two teams, each of which trying to be the first to get to the top of a mountain within the game. In order to move up the mountain teams must correctly answer questions based on social functioning while co-interacting with the ‘game board’ presented on a multitouch table. These questions cover four categories: knowledge (anatomical and pathological matters), reasoning (situational exercises), action (role playing exercises), cohesion (jokes and sayings). For example, a question may be “your friends are talking at the same time and you cannot follow the conversation. What do you do”? (Lloréns et al., 2015, p. 3). The Self-Awareness Deficits Interview (Simmond & Fleming, 2003) and Social Skills Scale were used to measure participants’ awareness of deficits and their functional implications, as well as improvement in social skills (Lloréns et al., 2015). Results indicated that participants benefitted from the videogame-based intervention across all clinical measures with improvements in planning skills, perception of deficits, and perception of the implications of deficits. The number of participants with disturbed social interaction skills decreased from 31 at base line to 14 post-intervention. Moreover, acceptance of the videogame-based intervention was high.

4.1 Conclusion

Taken together, the discussed studies show preliminary support for the use of technology-based interventions in rehabilitation of social functioning among ABI patients. Patients showed improvement from pre- to post-intervention on a number of skills (Januth et al., 2016; Hillari et al., 2009; Hoover & Carney, 2014; Rietdijk et al., 2018; Grechuta et al., 2016; Kolk et al., 2019; Lloréns et al., 2015). Importantly, improvements in quality of life are higher following the intervention than for a control group (Janssen et al., 2016), thus confirming the added benefit of an intervention; and the improvement was similar to that of in-person therapy sessions (Meltzer et al., 2015), thus suggesting that technology-based interventions may be equivalent to traditional interventions. However, these latter two studies were at high risk of bias, and also targeted only two of the available interventions;

more research is needed to confirm that technology-based interventions are superior over non-treatment and equivalent to traditional treatment.

With regards to usability, results were overall promising. Especially the high retention rates reported by Mallet et al. (2016) and Pugliese et al. (2018) are encouraging, as therapy adherence is a major factor in its effectiveness and poor adherence and drop-out is a recurring issue. Studies that addressed tablet-based interventions commented on the increase of accessibility that tablets provide and the opportunity that they create for independent, home-based therapy practice - and the ability for therapists to monitor these remotely. Most interventions incorporated a social interaction component, either directly with a therapist or with other ABI patients (Meltzer et al., 2015; Meulenbroek & Cherney, 2017; Hoover & Carney, 2014; Rietdijk et al., 2018; Grechuta et al., 2016; Kolk et al., 2019; Lloréns et al, 2015). This is rather unsurprising given that the objective of the therapies was to increase social functioning, yet interventions that can be completed individually may increase flexibility in the sense that the patient can use the app whenever it suits them best.

Videoconferencing technology could be an especially promising tool for administering rehabilitation for social functioning. In addition to booking promising results in terms of social functioning improvements and usability ratings, they are also easily accessible as they require technology that most people already own (e.g. smartphones) or is relatively cheap (e.g. tablets) so that patients can either invest in a device themselves, or get one on loan from the therapist. This may prove to be a barrier to VR-based interventions, which were administered in a therapy setting with assistance from a health professional required.

An overall limitation is that many of the studies included in this review are either pilot or preliminary studies, with low participant numbers and therefore limited statistical power. In addition, most studies used a pre-post test design, making it impossible to determine the added benefit of the intervention over simply improvement with time as well as to assess the equivalence of the technology-based intervention to established therapies. While the field has shown to have potential, more randomised-controlled trials are needed to gather statistically valid results and to discover further possibilities.

Acknowledgements: The authors thank Tim McKenzie for his help with the eligibility screening of papers for this systematic review.

Conflict of interest: The authors declare no external funding was received for the current project, and that they are unaware of any conflicts of interest (financial or otherwise).

5. REFERENCES

Bhogal, SK, Teasell, RW, Foley, NC, and Speechley, MR, (2003), Community reintegration after stroke, *Topics in Stroke Rehabilitation*, **10**, *2*, pp. 107-129.

Bosc, M, (2000), Assessment of social functioning in depression, *Comprehensive Psychiatry*, **41**, *1*, 63-69.

Cameirão, MS, Badia, SB, Oller, ED, and Verschure, PF, (2010), Neurorehabilitation using the virtual reality based Rehabilitation Gaming System: methodology, design, psychometrics, usability and validation, *J. Neuroengineering and Rehabilitation*, **7**, *1*, pp. 1-14.

Dewan, MC, Rattani, A, Gupta, S, Baticulon, RE, Hung, Y-C, Punchak, M, Agrawal, A, Adeleye, AO, Shrime, MG, Rubiano, AM, Rosenfeld, JV, and Park, KB (2018), Estimating the global incidence of traumatic brain injury, *Journal of Neurosurgery*, **130**, *4*, pp. 1080-1097.

Dores, AR, Miranda, MJ, Carvalho, IP, Mendes, L, Barbosa, F, Coelho, A, de Sousa, L, and Caldas, AC, (2012). Virtual City: neurocognitive rehabilitation of acquired brain injury, *Proc. IEEE 7th Iberian Conference on Information Systems and Technologies (CISTI)*, Madrid, pp. 1-4.

Gamito, P, Oliveira, J, Coelho, C, Morais, D, Lopes, P, Pacheco, J, Brito, R, Soares, S, and Barata, AF, (2017), Cognitive training on stroke patients via virtual reality-based serious games, *Disability and Rehabilitation*, **39**, *4*, pp. 385-388.

Grechuta, K., Ballester, B., Duff, A., Duarte, E., and Verschure, P. (2014), Intensive language-action therapy in virtual reality for a rehabilitation gaming system, In *Proc. 10th Intl Conf. Disability, Virtual Reality & Associated Technologies*, Gothenburg, pp. 265–273

Hillari, K, Lamping, DL, Smith, SC, Northcott, S, Lamb, A, and Marshall, J, (2009), Psychometric properties of the Stroke and Aphasia Quality of Life Scale (SAQOL-39) in a generic stroke population, *Clin. Rehabil.*, **23**, *6*, pp. 544–557.

Hoover, E, and Carney, A, (2014), Integrating the iPad into an Intensive, Comprehensive Aphasia Program, *Seminars in Speech and Lang.*, **35**, *1*, pp. 25-37.

Hopwood, V, Nanjing, DA, Donnellan, C, and Shiatsu, D (2010), Acquired brain injury: stroke, cerebral palsy and traumatic brain injury, In *Acupuncture in Neurological Conditions* (Hopwood & Donnellan, eds.), Churchill, pp. 99-123.

Intercollegiate Stroke Working Party (2012), *National clinical guideline for stroke, 4th edition*. Royal College of Physicians, London. eISBN 978–1–86016–493–4.

Janssen, H, Salaris, M, Quinn, R, Jordan, LA, Galvin, R, and Vietch, K, (2016), Tablet computers may contribute to better stroke survivor quality of life one month after discharge from inpatient rehabilitation, *Smart Strokes*, Canberra, pp. 1186-1192

Januth, S, Urwyler, P, Blackenberger, S, Perny, S, Wyss, C, Renngli, J, Mitache, AV, Muri, R, and Nef, T, (2016), A new generation in Aphasia therapy – Tablet-based rehabilitation of speech and language, *3rd Swiss Federation of Clin. Neuro-Societies Congr.*, Basel, pp. 63,

Kizony, R, Weiss, PL, Elion, O, Harel, S, Baum-Cohen, I, Krasovsky, T, Feldman, Y, and Shani, M, (2014), Development and validation of tele-health system for stroke rehabilitation, *Intl J on Disability and Human Development*, **13**, *3*, pp. 361-368.

Kolk, A, Saard, M, Pertens, L, Kallakas, T, Sepp, K, and Kornet, K, (2019), Structured Model of Neurorehab: A Pilot Study of Modern Multitouch Technology and Virtual Reality Platforms for Training Sociocognitive Deficit in Children with Acquired Brain Injury, *Appl. Neuropsychology: Child*, **8**, *4*, pp. 326-332.

Lloréns, R, Colomer-Font, C, Alcañiz, M, and Noé-Sebastián, E, (2013), BioTrak virtual reality system: effectiveness and satisfaction analysis for balance rehabilitation in patients with brain injury, *Neurología (English Edition)*, **28**, *5*, pp. 268-275.

Lloréns, E. Noé, J. Ferri and M. Alcañiz, (2015), Videogame-based group therapy to improve self-awareness and social skills after traumatic brain injury, *J. of NeurorEngineering Rehabil.*, **12**, *37*,

Mallet, K, Shamloul, R, Corbett, D, Finestone, H, Hatcher, S, Lumsden, J, Momoli, F, Shamy, M, Stotts, G, Swartz, R, Yang, C, and Dowlatshahi, D, (2016), RecoverNow: Feasibility of a Mobile Tablet- Based Rehabilitation Intervention to Treat Post-Stroke Communication Deficits in the Acute Care Setting, *PLoS One*, **11**, *12*, pp. e0167950.

McDonald, S, Togher, L, and Code, C, (1999), The nature of traumatic brain injury: Basic features and neuropsychological consequences, In *Communication disorders following traumatic brain injury* (McDonald, S, Code, C & Togher, L, Eds), Psychology Press, New York, pp. 19-54.

Meltzer, JA, Harvey S, and Baird, A, (2015), Evaluation of TeleRehab effectiveness for post-stroke communication disorders, *World Stroke Org.*, **10**, *4*, pp. 83.

Meulenbroek, P, and Cherney, LR, (2017), Training workplace social skills after traumatic brain injury using work-related communication training for employment readiness (WoRCTER), a computerized role-play programme, *Brain Injury*, **31**, *6-7*, pp. 784-785.

National Heart, Lung, and Blood Institute (2020), *Study Quality Assessment Tools*. [Online, accessed April 20 2020]. Available: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

OECD Skills Studies (2015), Learning contexts, skills and social progress: a conceptual framework, in *The Power of Social and Emotional Skills* (Schleicher, A, Eds.), OECD Publishing, 2015, pp. 34.

Pugliese, M, Ramsay, T, Shamloul, R, Mallet, K, Zakutney, L, Corbett, D, Dukelow, S, Stotts, G, Shamy, M, Wilson, K, Guerinet, J, and Dowlatshahi, D, (2019), RecoverNow: A mobile tablet-based therapy platform for early stroke rehabilitation, *PLoS One*, **14**, *1*, pp. e0210725.

Rietdijk, R, Power, E, Brunner, M, and Togher, L, (2018), A single case experimental design study on improving social communication skills after traumatic brain injury using communication partner telehealth training, *Brain Injury*, **33**, *1*, pp. 94-104.

Sanchez, L, Courtine, A, Gerard-Flavian, G, Dauber-Natali, A, Signeux, J, Bourgain, M, Provot, T, Cifuentes, CA, and Munera, M, (2019), The use of a social assistive robot: NAO for post strokes rehabilitation therapy: a preliminary study, *Computer Methods in Biomechanics and Biomedical Engineering*, **22,** *sup1*, pp. S478-S480.

Simmond, M, and Fleming, J, (2003), Reliability of the self-awareness of deficits interview for adults with traumatic brain injury, *Brain Injury*, **17**, *4*, pp. 325-337.

The State of Queensland (Queensland Health), Acquired Brain Injury Outreach Service (ABIOS), (2018), *Cognitive and Behavioural Changes and Strategies.* [Online]. Available: https://www.health.qld.gov.au/__data/assets/pdf_file/0028/390835/cog_behav_strat_fsw.pdf.

Validation of a Virtual Reality Environment for Exposure Therapy in Obsessive-Compulsive Disorder

I Fajnerová[1], A Francová[2], K Taranzová[3], E Nosková[4], B Darmová[5], P Stopková[6]

[1,2,3,4,5,6] National Institute of Mental Health

Topolová 748, Klecany, CZECH REPUBLIC

[1]*iveta.fajnerova*@nudz.cz, [2]*anna.francova*@nudz.cz, [6]*pavla.stopkova*@nudz.cz

[1-6]*www.nudz.cz/en*

ABSTRACT

Obsessive-compulsive disorder (OCD) is characterized by recurrent, repetitive, and unwanted thoughts or impulses triggering significant anxiety. Exposure and response prevention is currently the first-line therapy for OCD. In the current research, we tested the feasibility of a virtual environment (“VR house”) that incorporates OCD-specific items from four symptom dimensions: ‘contamination’, ‘symmetry’, ‘checking’, and ‘hoarding’. The goal of this ongoing feasibility study was to confirm the potential of the VR house in inducing anxiety in patients with OCD (n = 26) in comparison to matched healthy controls. During a single session, participants were asked to approach a set of 10 stimuli (covering all four OCD dimensions), and rate their current intensity of distress caused by observing this object. We used subjective units of distress (SUDS) as a distress measure (scale 0 to 5). In addition, the severity of OC symptoms was assessed prior to the session. Before and after the session, participants completed questionnaires assessing subjective levels of anxiety (STAI-6). All participants also completed the questionnaires evaluating their sense of presence in VR and experienced simulator sickness. Between-subject design was used to compare SUDS ratings of patients and healthy controls. The preliminary results show that the OCD group reports elevated levels of distress and anxiety when confronted with OCD-relevant stimuli compared to the control group. Our preliminary data suggest that the VR house environment is a suitable tool for VR exposure therapy in OCD patients as it demonstrated symptom provocation specific to OCD patients.

1. INTRODUCTION

Obsessive-compulsive disorder (OCD) is a severe neuropsychiatric disorder defined by the presence of obsessions, compulsions or both. Obsessions are intrusive recurrent and persistent thoughts, images or urges; compulsions are characterized by repetitive behaviors (e.g., washing, checking, arranging things in a specific way) or mental acts (e.g., counting). These are often performed to prevent obsessive thoughts from happening or make them disappear and temporarily reduce anxiety (APA, 2013). OCD symptoms (OCS) induce personal distress, are time-consuming and can strongly interfere with professional, social and personal life. The symptoms are very heterogeneous, and therefore, a dimensional approach (Summerfeldt et al., 1999) to OCS has been proposed in clinical research, including dimensions of “contamination/cleaning”, “symmetry/ordering”, “fear-of-harm/checking” and “hoarding”. The most common treatment for OCD is a combination of cognitive-behavioral therapy (CBT) and antidepressant medication. Specifically, exposure and response prevention (ERP) seems very useful for treating OCD (Hezel & Simpson, 2019). This involves progressive, deliberate and voluntary exposure to stimuli triggering obsessive thoughts while knowingly averting compulsive, avoidance or neutralization behavior (response prevention).

Virtual reality exposure therapy (VRET) and its application in OCD: Virtual reality (VR) exposure therapy seems to be a good alternative to in vivo (standard) exposure techniques. In VRET, the person is immersed in a virtual environment whose characteristics confront them with a feared situation or stimuli and correspond with symptoms-triggering real-life situations. Often, it is easier, economical and safer to access these stimuli in a virtual environment than in real life. There is already evidence showing that VRET can effectively treat anxiety disorders such as specific phobias or PTSD (for a review, see Maples-Keller et al., 2017).

The first study on OCD and VRET (Kim, 2008) showed that after provocation by a virtual scenario, patients performed more checking behaviors and reported higher anxiety before checking. These findings demonstrated that some of the behavioral patterns of OCD patients could be replicated in VR. Similarly, Laforest et al. (2016) assessed contamination fears and compulsions by comparing OCD patients and controls immersed in a neutral virtual environment (clean room) and filthy public restroom, showing anxiety increase (assessed by self-report and heart rate) among OCD patients. Cárdenas et al. (2012) later developed virtual public toilets, together with a virtual bus, a restaurant, and a bedroom. The above-listed studies suggest that immersive VR environments, including OCD-specific stimuli, can induce anxiety and can be used to provide exposure (Bouchard et al., 2019). However, to our knowledge, there is only one pilot study assessing the efficacy of VRET in OCD (Laforest et al., 2016) examining the effectiveness of a CBT programme with VRET in three patients with contamination OCS. There was a significant reduction in intensity and severity of OCS in all participants, but the global improvement was apparent only for two of them, as the OCS of the third patient were less specific to toilets. Besides variable symptomatology, the necessity of intensifying the consequences of actions visible in VR environments and creating the narrative specific for individual patients have been pointed out. Importantly, no bigger randomized control trial has been conducted for OCD treatment using VRET. Recently, a VR game has been developed (van Bennekom et al., 2021) to provoke and assess OCD symptoms from three symptom dimensions (including items such as burning gas, dirty sink and messy table). Nevertheless, this game is based on video images when a first-person video of intervention or checking behavior is shown when a participant chooses to check. Thus, its goal is rather to recognize OCD symptoms. To our knowledge, it seems that a complex VR environment that would incorporate all OCD dimensions and its primary purpose is exposure therapy has not been created yet. To overcome the problem of symptoms' heterogeneity, we, therefore, designed a prototype of a VR environment in concordance with the dimensional model and its four dimensions (Francová et al., 2019).

2. METHODS

2.1 Study Sample

In total, 30 patients diagnosed with Obsessive-compulsive disorder F42.X were tested using a set of 10 VR exposure stimuli to demonstrate its feasibility, validity and the potential of VR exposure scenarios to provoke anxiety and compulsive behavior in OCD patients in contrast to healthy subjects (n = 30). Four patients (together with matching healthy controls) were excluded from the dataset due to comorbidity with a personality disorder or revised diagnosis in the course of treatment (post-study).

The groups' sizes represented in this pilot feasibility study demonstrate the distribution of OCD dimensions and their incidence in the CBT programme run at National Institute of Mental Health (NIMH) corresponding to main OCS dimensions associated with "contamination/cleaning" (N=13), "control/checking & symmetry" (N=10) or combination of checking and contamination symptoms (N=2) and hoarding (N=1).

2.2 Virtual Reality Exposure Therapy (VRET) environment

2.2.1 VRET Technical Equipment & SW. The VR scenarios are created using the VR game engine Unity®Pro (https://unity3d.com/). The head-mounted display (HMD) HTC Vive Pro Eye will be used for immersive VR experience, providing accurate tracking of the person's head and hand movements, and eye-tracking crucial for the analysis of the patients' behaviour in a virtual environment. The participant experiences the virtual scene from a first-person perspective with virtual hands displayed instead of VR controllers.

2.2.2 VRET Experimental Design. The participant is immersed into a virtual environment that is specifically designed to provoke OCS typical for home settings with scenarios corresponding to dimensions of "contamination/cleaning", "fear-of-harm/checking", "symmetry/ordering", and "hoarding". The VR scene displays a family house (with a bedroom, kitchen etc.).

To address the VRET feasibility, a standardized set containing the 10 most common stimuli that OCD patients react to and covering all OCD dimensions was used as short provocation scenarios. The therapist guides the patients to individual stimuli in a predefined order one-by-one and asks them to rate their current level of anxiety (scale 0-5). The set included three stimuli for every dimension (C,S,CH) except hoarding, with only one stimulus present. Stimuli were selected based on a pilot study conducted in a smaller sample of eight OCD patients. Approximately 19 stimuli were identified and tested in the pilot study. From these, 10 final stimuli were then selected to be used during validation, mainly due to the time demands of the examination. The selection of items has been tested to ensure that each dimension was represented and that the stimuli were sufficiently specific to OCD (we, therefore, excluded particularly extreme stimuli, e.g., fecal matter, which may elicit nonspecific responses even in the control group).

Figure 1. *Screenshots illustrate situations within the virtual home environment corresponding with dimensions "contamination/cleaning", „fear-of-harm", "symmetry", and "hoarding".*

2.3 *Psychiatric Scales and Psychometric Methods*

To address the severity of OC symptoms, the Yale–Brown Obsessive Compulsive Scale (Y-BOCS) was evaluated based on a structured interview by the psychiatrist. The patients also report subjective anxiety levels (Beck Anxiety Inventory; BAI). In the VRET session, participants fill in (before/after) questionnaires assessing subjective anxiety (STAI-6, 6-item Anxiety State Inventory derived from the Spielberger State-Trait Anxiety Inventory) potentially triggered by the VRET exposure. During the VRET sessions, participants are asked to rate the current level of perceived anxiety/discomfort using (SUDS - Subjective Units of Distress scale; validated in anxiety research, for example Takac et al, 2019) a verbal analogue scale ranging from 0 (no anxiety/distress) to 5 (extreme anxiety/distress). To address potential VR-specific effects on evaluated parameters, after the VRET session, all participants complete questionnaires assessing sense of presence (SUS, Slater-Usoh-Steed Presence Questionnaire) and Simulator Sickness questionnaire (SSQ).

2.4 *Study Procedure*

After giving informed written consent, the patient was first evaluated by the psychiatric scales (Y-BOCS, BAI) assessing present symptomatology. During the VRET session, the participant first fills-in the STAI-6 questionnaire and then the 10-scenarios set has been performed in VR. After the VRET exposure, the participants filled in STAI-6 and VR presence and cybersickness questionnaires.

Table 1. *The list of 10 selected scenarios/stimuli presented during the VR exposure in individual participants divided into four typical OCD dimensions.*

Contamination/cleaning	**Checking**	**Symmetry**	**Hoarding**
blood on the sink mirror	porcelain shards on the floor	crooked picture frame	room filled with boxes
puddle of dog urine	gas stove	tablecloth crooked	-
rotten pear on the kitchen counter	knives on the kitchen counter	untidy dishes	-

2.5 *Statistical Analysis*

All data were preprocessed and analysed using statistical software Statistica 64 (TIBCO software Inc.). Based on a normal distribution of individual measures, the data were analysed using parametric statistical methods. Specifically, simple group differences were analysed using Student T-test, and potential relationships between individual measures were analysed using Pearson's correlations. In addition, the effect of VR exposure on repeated evaluation of anxiety (STAI-6) was analysed using GLM with repeated measures ANOVA with a categorical group factor. For all analyses, we set the significance level at $p = 0.05$.

3. RESULTS

3.1 Study Sample Specification and Measured Variables

In total, 26 OCD patients and 26 healthy volunteers were included in the analysis. The patients showed mild to severe OCD symptoms and were treated for OCD (illness duration) on average 3.86 (SD =1.36) years. The control group subjects were recruited to match the demographics of individual OCD patients, therefore, the groups are comparable in means of demographic characteristics (age and education (level 1-elementary school, 5 - university degree)). The male/female ratio was also comparable in both groups. See Table 2 for more details.

Table 2. *Demographic specification of the matched experimental (OCD) and control (HC) group.*

Demographic variable	OCD group (n=26)			HC group (n=26)			Group comparison	
	Mean	*SD*	*Min-Max*	*Mean*	*SD*	*Min-Max*	*t-test / Cramer's V*	*p*
Age	33.54	10.04	18-60	33.39	12,72	18-61	0.048	0.962
Education	3.88	1.33	1-5	4.19	1.20	1-5	-0.887	0.380
Sex	15 males/ 11 females			13 males/ 13 females			0.30	0.581

The groups (OCD vs. HC) differed in several measures (see Table 3). The Y-BOCS symptom severity score was significantly higher in the OCD group, as expected based on the OCD diagnosis. Both groups also differed in anxiety measures, BAI (anxiety present in the last week) and STAI (anxiety rated pre and post VR exposure).

Table 3. *Group comparison of selected psychiatric scales and VR-related measures.*

Measure/ Scale	OCD group (n=26)			HC group (n=26)			Group comparison	
	Mean	*SD*	*Min-Max*	*Mean*	*SD*	*Min-Max*	*t value*	*p*
Y-BOCS	19.68	10.29	7-35	0,48	1.5	0-7	8.497	< 0.001
BAI	19.14	8.37	4-31	4.62	4.76	0-15	7.530	< 0.001
STAI pre	46.67	8.89	30-66	31.79	9.53	20-50	5.816	< 0.001
STAI post	44,10	24.59	0-133	26.67	7.71	20-46.5	3.449	0.001
SUS	26.00	6.25	16-42	24.46	6.67	13-38	-1.140	0.261
SSQ	23.76	12.75	7.5-48.6	10.21	13.98	0-56	3.214	0.003

Legend: Y-BOCS (Yale–Brown Obsessive Compulsive Scale); BAI (Beck Anxiety Inventory); STAI (STAI-6, Six-Item State Anxiety Scale); SUS (Slater-Usoh-Steed Presence Questionnaire); SSQ (Simulator Sickness Questionnaire).

3.2 SUDS Score Differences

First, we tested the assumption that stimuli displayed in a virtual house environment can effectively simulate an exposure situation and thus induce real anxiety or distress measured by SUDS (Subjective Units of Distress) in patients using the presented exposure scenario/stimuli. Our assumption was that the scenarios/stimuli selected in the virtual environment are relevant for OCD and would affect patients in the experimental group, but in contrast, would not induce anxiety in the control group.

The SUDS score was calculated as a cumulative score of individual SUD ratings for the whole set of 10 stimuli/scenarios (score range 0-50). We included all patients in the analysis regardless of the predominant symptom dimensions (n = 26), as we were only concerned with the difference in reported SUDS compared to matched healthy volunteers (n = 26). The hypothesis was tested using the Student's t-test. The SUDS rating scores were significantly higher ($t(50) = 6.513$, $p < 0.0001$) in OCD patients (Mean (SD) = 18.54 (10.59), range 0-41) compared to healthy subjects (Mean (SD) = 3.77 (4.65), range 0-16).

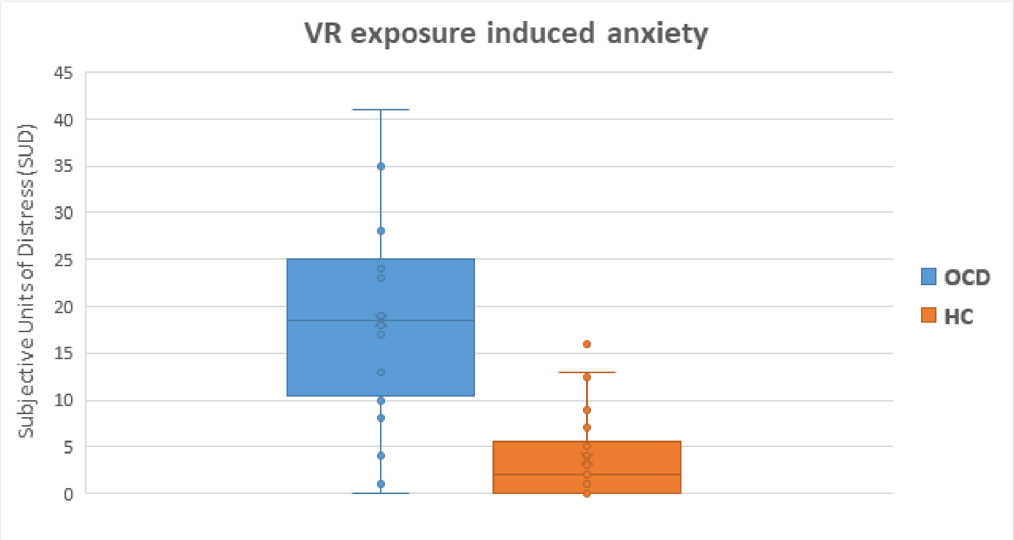


Figure 2. *Group comparison of the VRET induced anxiety measured using subjective units of distress scale (SUDS) calculated as total scores rated by OCD patients and control subjects in a set of 10 stimuli.*

3.3. STAI Score Differences

We further hypothesized that the difference in anxiety ratings would be evident in the STAI-6 questionnaire administered to both groups before and after VR exposure. In line with SUDS ratings, we expected the group of OCD patients to show higher scores in the subjective rating of anxiety state reflected by the STAI-6 questionnaire after exposure when compared to the group of healthy volunteers. Moreover, the STAI score will be increased in OCD patients after the VR exposure session (compared to baseline evaluation prior to the VR session), in contrast to healthy subjects that should not exhibit any changes in a rated anxiety state. ANCOVA Both group effect and interaction group*STAI-score-change has been expected.

The GLM model with repeated ANOVA (STAI-pre vs. STAI-post variables, within effect) and group factor showed 1) significant main group effect in the STAI-6 scores rated by patients and controls ($F(1,50) = 28.996$, $p < 0.001$) and 2) significant main repetition effect in means of decrease in STAI score after the VR exposure session (STAI post vs. pre, $F(1,50) = 11.757$, $p = 0.001$). Contrary to our expectation, no interaction between STAI change and the group factor has been identified ($F(1,50) = 0.200$, $p = 0.656$) as both groups showed a comparable drop in rated anxiety (about 5 points).

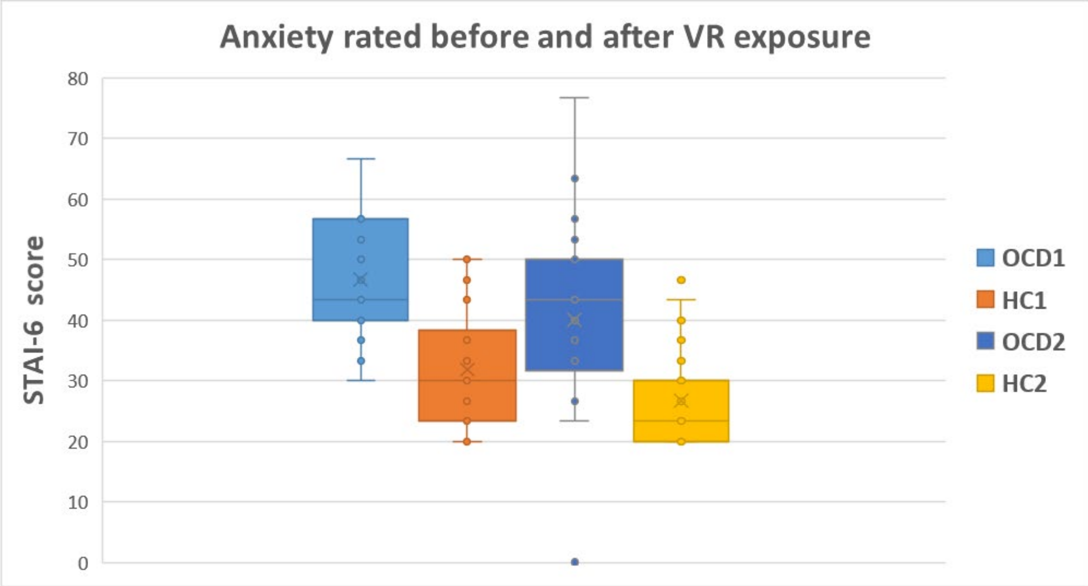


Figure 2. *Group comparison of the STAI-6 score evaluated subjective anxiety scores measured before (OCD/HC1) and after (OCD/HC2) VR exposure sessions by OCD patients and control subjects.*

3.4 Symptoms Severity and its Relation to SUDS Ratings in OCD Patients

Based on previous studies (van Bennekom et al., 2021), symptom severity rated by the Y-BOCS scale in OCD patients is significantly related to the degree of subjectively reported distress on the SUDS rating scale. We tested this assumption in our data using a correlation analysis. Based on Pearson's correlation coefficient, no significant correlation was found between the tested variables in our OCD patients. Pearson's correlation coefficient for Y-BOCS and SUDS (r = 0.247, p-value of 0.266) and BAI (r = 0.243 with p = 0.257) revealed no correlation between the tested variables. Importantly, the anxiety state evaluated using STAI-6 after the VR experience did not correlate with the total SUDS score rated during this experience (r = -0. 095, p = 0.673).

3.5 VR Presence and Cybersickness in Respect to SUDS Scores Rated by OCD Patients

Previous studies also suggested a direct association between the SUDS ratings and the sense of presence in VR evaluated by the patients (Belloch et al., 2014; Laforest et al., 2016). Therefore, we were interested in whether reported exposure related anxiety (SUDS) was related to how immersed patients felt in the virtual environment (VR presence). Based on Pearson's correlation coefficient for the SUS questionnaire measuring subjective sense of presence in the virtual environment, Pearson's r = -0.443, with a p-value of 0.075 showed a moderate correlation that did not reach significance. Please note that the data are only provided for a subset of 17 patients due to incomplete or partially invalid data from VR feedback questionnaires in nine patients.

Finally, we investigated whether virtual environment-induced nausea (cybersickness) may impact how the VR experience has been rated by OCD patients in means of (sense of presence). No significant correlation was found between the tested variables (SUS and SSQ) Pearson's correlation coefficient r = -0.202 with p-value = 0.438 (N=17). Also no correlation was found between SSQ and SUDS score (r = 0.076, p = 0.771). Please note, the VR sense of presence rated using the SUS scale did not differ between OCD patients and healthy controls. In contrast, patients reported a higher occurrence of cybersickness symptoms (SSQ score) than healthy subjects (see Table 3 for detailed results).

4. CONCLUSIONS

The presented study confirmed the feasibility of the created VR house environment to evoke typical manifestations in OCD patients in contrast to control subjects that rated no or minimal distress in the same virtual scenarios. This is in line with our preliminary data suggesting that the VR house environment could represent a suitable tool for VR exposure therapy in OCD patients. It demonstrated symptom provocation specific to OCD and with other previous studies that validated various environments for VRET for OCD (e.g. van Bennekom et al., 2017; Laforest et al., 2016; Belloch et al., 2014; Kim et al., 2008).

Nevertheless, contrary to our expectations, the subjectively evaluated anxiety measured using STAI-6 before and after the VR exposure session showed a decrease in STAI score that could be observed in both tested groups. This finding suggests that anxiety decreased after VR exposure in general. Furthermore, based on verbal reports of the participants, the evaluation performed before VR exposure is often associated with some distress due to expectations and fear of the unknown they will encounter in VR, while after the exposure session, the feeling of relaxation associated with the completed task and/or well managed exposure was evoked. This observation thus could explain the contradictory data and missing correlation between the SUDS ratings and the STAI anxiety state evaluated after the VR experience.

In contrast to previous studies (e.g. Kim et al, 2010), SUDS ratings of the VR exposure stimuli were not associated with symptom severity (Y-BOCS, BAI). This is in line with findings of a previous study by van Bennekom et al. (2021). This negative finding is not surprising as the SUDS ratings were calculated as a cumulative score for a set of scenarios, where only a small subset was associated with the patient symptomatology. A relatively small sample, however, does not allow us to test this assumption by dividing the SUDS ratings into four clusters and evaluating their association with symptoms severity for the respective subset of patients. This matter should be addressed in future studies.

Finally, we did not identify a significant association between SUDS and sense of presence identified in previous studies (Belloch et al., 2014; Inozu et al, 2021), however, this could be related to the small sample size as the tendency towards moderate positive correlation has also been revealed in our data. Despite the increased cybersickness symptoms reported by OCD patients in contrast to control subjects, the SSQ score was not associated with the rated sense of presence in the virtual environment. Increased cybersickness indicated in OCD patients thus could be related to the unpleasant experience of the VR exposure with OCD relevant symptoms (Kim et al., 2008). It was previously suggested (Bouchard et al., 2011) that VR-induced nausea and visuomotor disturbances reported by the patients could be confused with anxiety symptoms (perspiration, general discomfort, difficulty concentrating, etc.). However, no correlation with rated SUDS was identified.

In conclusion, the presented data confirm the feasibility of the VR house environment for the exposure therapy in OCD. Future work should address some of the issues emerging in this preliminary feasibility study. Particularly, validity of individual scenarios in respect to the dimensional approach should be evaluated in a bigger sample of OCD patients including all subtypes. Moreover, a randomised clinical study aimed at VRET effectiveness should be conducted. In future studies, to address the validity or effectiveness of the VRET scenarios, it seems crucial to monitor physiological data to determine the induced mental and physical state of the subject (Meehan et al, 2002).

Acknowledgements: The presented study is supported by the European Regional Development Fund-Project "PharmaBrain" No. CZ.02.1.01/0.0/0.0/16_025/0007444 and the Technology Agency of the Czech Republic project BrainTech TP01010062 (subproject 04: VR house).

5. REFERENCES

American Psychiatric Association, (2013), Diagnostic and statistical manual of mental disorders (DSM-5®), American Psychiatric Pub.

Belloch, A, Cabedo, E, Carrió, C, Lozano-Quilis, JA, Gil-Gómez, JA, & Gil-Gómez, H, (2014), Virtual reality exposure for OCD: is it feasible?. *Revista de Psicopatología y Psicología Clínica*, *19*(1), pp. 37-44.

Bouchard, S, Laforest, M, Gamito, P, & Cardenas-Lopez, G, (2019), Using VR for Obsessive-Compulsive and Related Disorders. In *Virtual Reality for Psychological and Neurocognitive Interventions*, pp. 103-130, Springer, New York, NY.

Bouchard, S, Robillard, G, Renaud, P, & Bernier, F, (2011), Exploring new dimensions in the assessment of virtual reality induced side-effects. *J. Comput Inf. Technol*. 1, pp. 20–32.

Cárdenas, G, Muñoz, S, & Oviedo, P, (2012), Exposición virtual como herramienta para el tratamiento del trastorno obsesivo compulsivo. *Revista de investigación en psicología*, 15(2), pp. 89-98.

Francová, A, Darmová, B, Stopková, P, Kosová, J, & Fajnerová, I, (2019), Virtual Reality Exposure Therapy in Patients with Obsessive-Compulsive Disorder. In 2019 International Conference on Virtual Rehabilitation (ICVR), pp. 1-2, IEEE.

Hezel, DM, & Simpson, HB, (2019), Exposure and response prevention for obsessive-compulsive disorder: A review and new directions. *Indian journal of psychiatry*, 61(Suppl 1), S85.

Inozu, M, Celikcan, U, Trak, E, Üzümcü, E, & Nergiz, H, (2021), Assessment of Virtual Reality as an Anxiety and Disgust Provoking Tool: The Use of VR Exposure in Individuals With High Contamination Fear. *Cyberpsychology,* 15. doi: 10.5817/CP2021-1-7 Jerald,

Kim, K, Kim, CH, Cha, KR, Park, J, Han, K, Kim, YK, ... & Kim, SI, (2008), Anxiety provocation and measurement using virtual reality in patients with obsessive-compulsive disorder. *CyberPsychology & Behavior*, 11(6), pp. 637-641.

Kim, K, Kim, S, Cha, J, Rosenthal, M, Kim, JJ, Kim, I, & Kim, ChH, (2010), Development of a computer-based behavioral assessment of checking behavior in obsessive-compulsive disorder. Comprehensive psychiatry, 51, 86-93. doi: 10.1016/j.comppsych.2008.12.001

Laforest, M, Bouchard, S, Crétu, AM, & Mesly, O, (2016), Inducing an anxiety response using a contaminated Virtual environment: validation of a therapeutic tool for obsessive–compulsive disorder. *Frontiers in ICT*, 3, 18.

Laforest, M, Bouchard, S, Bosse, J, & Mesly, O, (2016), Effectiveness of In Virtuo Exposure and Response Prevention Treatment Using Cognitive–Behavioral Therapy for Obsessive–Compulsive Disorder: A Study Based on a Single-Case Study Protocol. Frontiers in psychiatry, 7, 99.

Maples-Keller, JL, Bunnell, BE, Kim, SJ, & Rothbaum, BO, (2017), The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders. *Harvard review of psychiatry*, *25*(3), pp. 103.

Meehan, M, Insko, B, Whitton, M, & Brooks Jr, FP, (2002), Physiological measures of presence in stressful virtual environments. *Acm transactions on graphics* (tog), 21(3), pp. 645-652.

Summerfeldt, LJ, Richter, MA, Antony, MM, & Swinson, RP, (1999), Symptom structure in obsessive-compulsive disorder: a confirmatory factor-analytic study. *Behaviour Research and Therapy*, 37(4), pp. 297-311.

Takac, M, Collett, J, Blom, KJ, Conduit, R, Rehm, I, & De Foe, A, (2019), Public speaking anxiety decreases within repeated virtual reality training sessions. *PloS one*, 14(5), e0216288.

van Bennekom, MJ., de Koning, PP, Gevonden, MJ, Kasanmoentalib, MS, & Denys, D, (2021), A Virtual Reality game to assess OCD symptoms. *Frontiers in Psychiatry*, 11, 1640. doi: 10.3389/fpsyt.2020.550165

van Bennekom, M, Kasanmoentalib, MS, de Koning, PP, Denys, D, (2017), A Virtual Reality Game to Assess Obsessive-Compulsive Disorder. *Cyberpsychology, Behavior and Social Networking*, 20(11), pp. 718-722. 10.1089/cyber.2017.0107

Soundspace: VR navigation using sound

Luís FIALHO[a], Jorge OLIVEIRA[a,b], Filipe LUZ[c,d]
[a]*EPCV / Lusófona University*
[b]*HEI-Lab / Lusófona University*
[b]*ECATI / Lusófona University*

Abstract. A spatial navigation task in virtual reality using auditory cues was developed to study navigational strategies in blindfolded sighted individuals. Twenty healthy adult participants were exposed to a VR scene, where the goal was to find the target sound without visual information in different tasks where navigational strategies were studied. The task consisted in moving to the sound target and then returning to the starting point, and after an interference period, the same task was performed without the sound target. The measures consisted of execution time, collisions and prompts during the task execution. The participants were assessed for general cognitive ability and memory with established neuropsychological tests. Performance was affected by task difficulty, but it was better at the retrieval phase of the experiment that corresponded to wayfinding strategy. However, only performance in the first (learning) was explained by global cognitive function. The data suggest the Soundspace VR as a feasible task to study spatial navigation using sound.

Keywords. Virtual Reality, Spatial Memory, Spatial Navigation, Sound

1. Introduction

Virtual reality may allow to replicate conditions close to real life situations [1,2], which comprise an asset for studying spatial navigation and spatial learning. Some studies point to a relationship between navigation performance in real and virtual environments [3] but it is not known how spatial processing operates in the absence of visual information. This study describes the development and test of a 3D virtual reality scenario using sound as cues to explore navigation strategies as local navigation and wayfinding. We aimed to test whether performance in this task correlates with cognitive functioning as assessed using classical neuropsychological tests and whether this relationship is modulated by the type of the navigation task.

Methods

1.1. Sample

20 adult participants were recruited from the general community, 14 male participants and 6 female participants, aged between 20 and 33 years-old, with an average age of 26 years (SD = 4 yrs).

1.2. Measures

The measures consisted of 1) Montreal Cognitive Assessment – MoCA, a cognitive screening test where the higher scores reflect better cognitive performance; 2) Wechsler Memory Scale - WMS-R, a brief test for assessment of memory ability where higher scores of General Memory Index reflect better memory skills; 3) Task performance based in execution time, no. of obstacle collisions and no. of prompts (verbal aids in the task).

1.3. Procedure

This study was approved by an ethics committee. Navigation was performed by walking in the real environment that was calibrated with the Soundspace VR for a 4X4 meter area in MovLab from Lusófona University in Lisbon, Portugal. Firstly, this task was centered in local navigation strategies since the auditory target cues were in the perceived environment, requiring locomotion to seek for the target sound. After performing a distraction task, the participants were exposed to the same conditions but without the auditory target cues. The participants were asked to move to the target location using only the auditory cues from objects that were played in object proximity so that representation of the environment would be crucial to effectively accomplish the task.At this stage, navigation required orientation in a form of wayfinding relying in spatial representation of a known environment using the environment cues to reach the target destination.

2. Results

The statistical analysis was conducted using non-parametric tests. The results suggested that difficulty level affected navigation performance ($p < .001$), but it was better at the retrieval based in wayfinding strategies than the learning phase based in local navigation strategies ($p < .01$). Navigation performance correlated with neuropsychological functioning only at the learning phase ($p < .05$).

3. Conclusion

The results point to an improvement in performance when search and locomotion strategies were replaced by spatial representation of the environment supported by wayfinding strategies. Overall data suggest the Soundspace VR as a feasible task to study spatial navigation and spatial learning using sound.

References

[1] Bohil CJ, Alicea B, Biocca FA. Virtual reality in neuroscience research and therapy. Nat Rev Neurosci. 2011 Nov 3;12(12):752-62. doi: 10.1038/nrn3122.

[2] Parsons, T. D. (2015). Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences. Frontiers in Human Neuroscience, 9, 660.

[3] Cushman, LA, Stein, K, Duffy, CJ (2008). Detecting navigational deficits in cognitive aging and Alzheimer disease using virtual reality. Neurology, 71, 888-895Diamond, A. (2013). Executive functions. Annual Review of Psychology, 64, 135– 68.

Assessment of spatial navigation in multiple sclerosis and anti-NMDA receptor encephalitis using virtual environments

S Rekers[1], G Cooper[2], J Heine[3], S Krohn[4], H Prüss[5], F Paul[6], C Finke[7]

[1,2,3,4,5,6,7] Department of Neurology,
Charité – Universitätsmedizin Berlin,
Berlin, Germany

[1,4,7]Berlin School of Mind and Brain,
Humboldt-Universität zu Berlin,
Berlin, Germany

[1]*sophia.rekers@charite.de,* [2]*graham.cooper@charite.de,* [3]*josephine.heine@charite.de,* [4]*stephan.krohn@charite.de,* [5]*harald.pruess@charite.de,* [6]*friedemann.paul@charite.de,* [7]*carsten.finke@charite.de*

[1,2,3,4,7] *www.cognitive-neurology.com,* [1,2,3,4,5,6,7] *www.neurologie.charite.de,* [1,4,7]*www.mind-and-brain.de*

ABSTRACT

Multiple sclerosis and anti-N-methyl-D-aspartate receptor (NMDAR) encephalitis are neurological disorders which frequently cause cognitive impairments and typically affect younger populations. In ongoing studies, we use the novel Virtual Environments Navigation Assessment for younger adults (VIENNA Young) to assess spatial navigation without confounding factors of motor simpairments. To investigate the feasibility and utility of VIENNA Young for cognitive assessments in multiple sclerosis and NMDAR encephalitis, we examine the navigation performance in association with standard neuropsychological tests and disease-specific neuropathology.

1. INTRODUCTION

Cognitive impairments affect more than 50% of patients with multiple sclerosis (Chiaravalloti & DeLuca, 2008; Sumowski et al., 2018) and most patients with anti-N-methyl-D-aspartate receptor (NMDAR) encephalitis (Finke et al., 2012; McKeon et al., 2018). Specifically, memory deficits are highly prevalent in both disorders. This clinical manifestation is in line with histopathological findings of neuroinflammation in the hippocampus, a region critical for memory and spatial navigation (Rosenbaum et al., 2018). In other disorders affecting the hippocampus, such as Alzheimer's disease, spatial navigation deficits have been identified as a highly sensitive preclinical marker (Bierbrauer et al., 2020; Coughlan et al., 2019). However, little research has been done to date on how spatial navigation abilities are impacted by neurological disorders typically affecting younger populations like multiple sclerosis and NMDAR encephalitis. This is partly due to the fact that spatial navigation is notoriously difficult to assess in a standardized way, especially in cases where there are potential impairments in motor functions and processing speed. Therefore, there is a need for assessments that provide a more detailed and thorough description of cognitive impairment in these disorders, which in turn could lead to improved cognitive rehabilitation due to an enhanced understanding and monitoring of impairment.

2. METHODS

We investigate the feasibility and performance of the Virtual Environments Navigation Assessment for younger adults (VIENNA Young) in a sample consisting of 80 patients with multiple sclerosis and 40 patients with NMDAR encephalitis in comparison to age-matched healthy controls. VIENNA Young is a passive spatial navigation paradigm in which the participants are asked to find a room in different virtual hallways using maps. Its administration takes approximately 15 minutes, including instructions and practice trials, and responses are not given under time pressure, making it applicable in clinical settings and appropriate to apply in patients with reduced processing speed. The VIENNA Young score is calculated from 12 trials and the paradigm distinguishes between updating and rotation errors, thus providing more detailed information about underlying deficits in impaired performance. It is intuitive to administer and does not require the use of a joystick or keyboard, thus allowing for assessment of spatial cognition without the potential confound of motor impairment. In the current studies, spatial navigation performance is examined in association with disease severity, questionnaire data, neuropsychological tests, and disease-specific neuropathological markers using magnetic resonance imaging.

3. OBJECTIVES

Previous studies have provided evidence for the feasibility and construct validity of VIENNA in middle-aged and older adults and have shown a significant decrease of performance with age (Rekers & Finke, 2019). The ongoing investigations serve to determine its feasibility and utility in younger clinical populations and to identify potentially necessary adaptions of the paradigm for this purpose. The current studies aim to determine whether performance in multiple sclerosis and NMDAR encephalitis differ in comparison to age-matched healthy controls and to investigate the relationship with patient-reported outcome measures and standard neuropsychological tests. Of particular interest is whether VIENNA Young performance is associated with (micro-)structural brain damage (e.g., lesion load and volume loss) and connectivity alterations.

4. OUTLOOK AND CONCLUSIONS

VIENNA Young aims to contribute to a more detailed cognitive assessment and a better characterization of the neuropsychological profile of patients with hippocampal dysfunction. With regard to the young age of the patients, undiagnosed and thus untreated cognitive deficits will have particularly severe and long-lasting effects on the quality of life and functionality at the workplace (Crouch et al., 2021; Ruet et al., 2013). If successful, the concept of the test could be transferred to training paradigms for cognitive rehabilitation.

5. REFERENCES

Bierbrauer, A, Kunz, L, Gomes, CA, Luhmann, M, Deuker, L, Getzmann, S, Wascher, E, Gajewski, PD, Hengstler, JG, Fernandez-Alvarez, M, Atienza, M, Cammisuli, DM, Bonatti, F, Pruneti, C, Percesepe, A, Bellaali, Y, Hanseeuw, B, Strange, BA, Cantero, JL, & Axmacher, N, (2020), Unmasking selective path integration deficits in Alzheimer's disease risk carriers, *Science Advances*, **6**, 35, pp. eaba1394.

Chiaravalloti, ND, & DeLuca, J, (2008), Cognitive impairment in multiple sclerosis, *The Lancet. Neurology*, **7**, 12, pp. 1139–1151.

Coughlan, G, Coutrot, A, Khondoker, M, Minihane, AM, Spiers, H, & Hornberger, M, (2019), Toward personalized cognitive diagnostics of at-genetic-risk Alzheimer's disease, *Proceedings of the National Academy of Sciences*, ***116***, 19, pp. 9285–9292.

Crouch, TA, Reas, HE, Quach, CM, & Erickson, TM, (2021), Does depression in multiple sclerosis mediate effects of cognitive functioning on quality of life? *Quality of Life Research*.

Finke, C, Kopp, UA, Prüss, H, Dalmau, J, Wandinger, KP, & Ploner, CJ, (2012), Cognitive deficits following anti-NMDA receptor encephalitis, *Journal of Neurology, Neurosurgery & Psychiatry*, ***83***, 2, pp. 195–198.

McKeon, GL, Robinson, GA, Ryan, AE, Blum, S, Gillis, D, Finke, C, & Scott, JG, (2018), Cognitive outcomes following anti-N-methyl-D-aspartate receptor encephalitis: A systematic review, *Journal of Clinical and Experimental Neuropsychology*, ***40***, 3, pp. 234–252.

Rekers, S, & Finke, C, (2019), Assessing spatial navigation in seniors and clinical settings: Stepwise progression from real-world to VR, *2019 International Conference on Virtual Rehabilitation (ICVR)*, pp. 1–2.

Rosenbaum, RS, Spiers, H, & Bohbot, V, (2018), Navigation and Memory, In *Human Spatial Navigation*, Princeton University Press, pp. 146–163.

Ruet, A, Deloire, M, Hamel, D, Ouallet, JC, Petry, K, & Brochet, B, (2013), Cognitive impairment, health-related quality of life and vocational status at early stages of multiple sclerosis: A 7-year longitudinal study, *Journal of Neurology*, ***260***, 3, pp. 776–784.

Sumowski, JF, Benedict, R, Enzinger, C, Filippi, M, Geurts, JJ, Hamalainen, P, Hulst, H, Inglese, M, Leavitt, V M, Rocca, MA, Rosti-Otajarvi, EM, & Rao, S, (2018), Cognition in multiple sclerosis: State of the field and priorities for the future, *Neurology*, ***90***, 6, pp. 278–288.

Moving from VR into AR using Bio-Cybernetic Loops and Physiological Sensory Devices for Intervention on Anxiety Disorders

Preyesse Arquissandás[1], David Ribeiro Lamas[2], Jorge Oliveira[3]

[1] Copelabs, University Lusófona, Av. Campo Grande 388 - 1749-024, Lisbon, PORTUGAL

[2] HCI, ULP/ Tallinn University, Tallinn, ESTONIA.

[3] HEI-Lab, University Lusófona, Av. Campo Grande 376 - 1749-024, Lisbon, PORTUGAL

[1]preyesse.arquissandas@alunos.ulusofona.pt, [2]drl@tlu.ee, [3]jorge.oliveira@ulusofona.pt

[1,2]www.ulusofona.pt, [3]www.hei-lab.ulusofona.pt

ABSTRACT

This study aimed to explore the benefits of an exposure session program using augmented reality (AR) on anxiety disorders of fear of snakes. The design of this study consisted of a pilot randomized controlled trial using adaptive system plugged with sensory device for psychophysiological data capture. The sample consisted of university students that have read and agreed with the consent inform. Thirty-five participants were randomly distributed by the experimental group consisting in non-immersive AR session using virtual fear cue stimulation with tasks and the therapist assessing the intervention. A battery of three five-minutes sessions to assess arousal levels were conducted. The system through algorithms, adapted the thresholds to the individual profile of each participant from historical data for assessing the outcomes. The results were encouraging by suggesting that the system was able to detected changes from pre-to-post exposures. Despite being a pilot study, these results highlight the potential role of adaptive non-immersive AR on anxiety disorders.

Keywords: Augmented Reality, Adaptive Systems, Anxiety Disorders, ECG, EDA.

1. INTRODUCTION

The research focused on behavioural therapy using VR and AR technologies in psychotherapy was proven to be effective particularly in the treatment of specific phobias [1]. According to behaviour therapy procedures, participants are exposed to fear inducing situations in a gradual and systematic fashion for phobia treatment. Such stimuli using the augmented reality (AR) could also be used to treat some psychological disorders, since the virtual elements can be used to replace the fear cue, thus avoiding facing the real danger of manipulating a dangerous animal or situation, allowing also to repeat such procedures in a controlled environment. Since AR allows the participants to experience a greater feeling of reality and sense of presence than VR, the avoidance of fearful stimuli might stabilize the assumption they have about the level of danger facing such dangerous creature or situation (i.e., a real snake). Therefore, including AR and VR applications in psychotherapy brings advantages such as the possibility of adjusting virtual or augmented environments to each participant profiles and controlling what is projected to them during the intervention. In addition, this approach also allows the therapists to manage the intervention in a controllable environment without audience [2], cost effective, and preserving all the confidentiality related with the data collected or stored.

2. METHODOLOGY

4.1 *Participants*

To analyse the usage of this application we invited a group of participants in a total of 35 university students (30 males and 5 females with ages ranging from 19 to 29 years, M = 23 years, SD = 10,22). A variety of socio-demographic coverage was found and according to question number, the distribution was: origin (Caucasian=26, Asian=2, African=5, Latin=2), gender (Male=30, Female=5) and age (19=3, 20=18, 21=6, 22=3, 23=2, 24=2, 29=1). They filled the self-report measures for fear of snake in a voluntary basis after consent agreement. The 30 self-reported questions of snake questionnaire (SNAQ) consist of (true; false) dichotomous responses format, in which higher scores describe higher snake phobia ratings.

4.2 *Procedure*

The AR exposure session was carried out in a one-session intervention related with fear of snakes for each of the participants. After a brief interview and a session objective explanation, the ECG (electrocardiogram) and EDA (electrodermal activity) sensors were attached to the participant's arm and palm and the AR application system was initialized. Following the initialization and the registration process, the system presented the fear cue and collected the electrical signals related to ECG (for heart rate) and EDA (for skin conductance) in three steps with 5 minutes each (baseline, AR snake, and rubber snake). On step 2, the participant was instructed to control the breathing and stay relaxed in order to lower down the anxiety level and avoid a virtual mouse being captured by the snake. At step 3, a cross-modal session with a rubber snake was carried out to measure activation to tactile and visual interactions. The psychophysiological signals were collected throughout the experimental session.

3. RESULTS

The AR intervention sessions produced a decrease in the participant's fear on a presence and interaction with their fear cue (snake). There was an important change in the avoidance of snake, since before the intervention, one of the participant that concluded the second stage, was not able to approach real or virtual snake and during the intervention, the variation in the ECG and EDA electrical signals value showed that in specific task condition (baseline vs. activation tasks), the participant presented high arousal levels (EDA&ECG >1.5%) in step 2, due to activation state and target-hit (when the snake kills the mouse in a one-session intervention) reporting: time(m)|activation|target-hit=1|0|0; 2-3|1|1; 4|1|0; 5|0|0. In step 3 the participant was able to manipulate the fear cue physically (rubber snake), which is a meaningful measure of improvement since the system not only induced anxiety, but it also diminished it through repeating exposure to the virtual snake, resulting in a successful reduction in the participant's fear and avoidance.

4. CONCLUSIONS

The relatively small sample size is one of main study's shortcomings. In the future, we plan to apply this type of interventions to a larger group of samples, in order to increase the confidence in this exposure format. Thus, the positive results of this first prototype suggest AR's potential in psychology as useful, as a therapeutic asset tool for several other psychological disorders and exposure interventions due to its effective and efficient capabilities in capturing psychophysiological signal changes. Overall, this paper provides the preliminary evidence for an adaptive and non-intrusive AR solution for exposure in anxiety disorders.

Acknowledgements: *Preyesse Arquissandás[1], David Ribeiro Lamas[2] and Jorge Oliveira[3] thanks to COPELABS – Cognitive and People-Centric Computing and COFAC / ULHT - Universidade Lusófona de Humanidades e Tecnologias for sponsoring this work. This work has also been (partially) funded by FCT strategic project COPELABS UID/04111/2020.*

5. REFERENCES

[1] Eichenberg C, (2011), Application of Virtual Realities in Psychotherapy: Possibilities, Limitations and Effectiveness., In J.-J. Kim (ed.), Virtual reality (pp 481-496). Rijeka: InTech.

[2] Glantz K, Rizzo A, Graap K, (2003), Virtual Reality for Psychotherapy: Current Reality and Future Possibilites., Psychotherapy: Theory, Research, Practice, Training, 40(1/2):55-67.

Dimensionality of Realism Across Media Literature

L Christophers[1], B Rooney[2]

[1, 2] School of Psychology, University College Dublin,
Belfield, Dublin 4, Ireland

[1]*lauren.christophers@ucdconnect.ie*, [2]*brendan.rooney@ucd.ie*,

[1,2] *https://www.mediaentertainmentlab.com/*

ABSTRACT

Realism is a vital part of entertainment and is theorised to facilitate flow, transportation, enjoyment and presence in mediated experiences (Busselle & Bilandzic, 2008; Tan, 2008). VR developers often strive for perfect fidelity that can induce a sense of presence or "there reality" (Kisker et al., 2019; Slater et al., 2020). Yet the construct of realism has been defined in diverse and inconsistent ways, rendering it difficult to work with in interdisciplinary research. The current paper uses a scoping review methodology to systematically synthesise the ways realism has been operationalised in previous literature exploring virtual reality and television. Using specific inclusion criteria, 797 abstracts were screen and the final sample of 85 included papers were coded. Using content analysis and thematic synthesis, we found that despite a rich multi-dimensional definition of realism, many studies continue to utilise a unidimensional operationalisation or conceptualisation of realism. Future research should explore the less examined dimensions pertaining to the "online" apparent reality users experience during media engagement.

1. INTRODUCTION

Media theory and empirical research has identified realism as a multi dimensional construct (Busselle & Greenberg, 2000; Hawkins, 1977; Shapiro & Chock, 2003). Broadly speaking we can categorise two different types of perceived realism processes. During media engagement we can experience an online "apparent reality" (Rooney et al., 2012) where we are perceiving the mediated stimulus as real, thus feeling present and involved. This can be considered a successful "illusion of non-mediation" (Lombard & Ditton, 1997). We can also make more conscious evaluative judgements of realism such as whether it is plausible or typical. These types of judgements can be described as relative realism (Rooney & Hennessy, 2013; Rooney et al., 2012) and involve a clear awareness of mediation. Thus multi-dimensional perceived realism involves dual awareness – one can be more attentive to the "content" of the simulation, and perceive an apparent reality but one can also consciously attend to the mediation itself thus making critical realism judgments (Tan, 2008). Within this attentional structure though, realism is a multi-dimensional construct. A broad range of different literature describes many types of realism. In this scoping review of media literature we aim to document and identify the diverse collection of realism dimensions. This diversity reflects a divergence in the focus of realism literature between immersive realistic features of media and technology and users' subjective experience of realism (Bouchard et al., 2012).

2. METHOD

2.1 Search Strategy & Eligibility Criteria

This review presented here is part of a larger project. A protocol for the larger scoping review was created and can be accessed on research gate:
https://www.researchgate.net/publication/328929887_The_Nature_of_Realism_Appraisals_in_Virtual_Reality_a

nd_Television_Protocol_for_a_Systematic_Scoping_Review. The current review aimed to examine dimensionality of realism conceptualisations and operationalisations across media literature. Scoping review methodology (Arksey & O'Malley, 2005; Levac et al., 2010) and PRISMA guidelines were followed (Moher et al., 2009). Our aim was to obtain a sample of conceptualizations relevant to many different media. The most efficient and feasible way to do this was to select two very different media. VR is a highly interactive and immersive media, with much research dedicated to the development of high fidelity and creating a sense of really being there (Slater et al., 2020). TV has been studied extensively in media and communication studies as a dominant, realistic media i.e. "What's real is what's on TV" (p.321, Watson & Hill, 2015). Thus, the use of TV and VR as the media in the search allowed insight to the breadth of literature examining realism as a concept and an effective examination of the dimensions of realism as they apply across different media.

The search was limited to research published since the year 2000. Only English language, peer-reviewed papers were included. The review included a variety of research – empirical research, theoretical or conceptual papers and position papers were all included. The proposed review focused on realism regarding TV and VR be included, realism had to be a variable, an outcome (in an empirical or scientific study) or a focus (e.g. a position paper in arts and humanities). To obtain a manageable selection of studies and to retain a clear focus in the review, the media (TV or VR) of focus in included papers had to include a "mediated message" of some kind i.e. a narrative or story. For example, papers examining VR as a use for surgical simulation, dental practice simulation or real estate simulation were excluded.

2.2 Screening, Extraction and Analysis

Two researchers independently screened 797 abstracts. Applying exclusion criteria (as outlined in the protocol), 588 papers were removed, and the remaining 209 relevant full texts were reviewed. The final sample was 85 included papers, from which data were extracted in the form of conceptualisations and operationalisations of realism. Using EPPI Reviewer Software IV (Thomas & Harden, 2008) we collected and thematically synthesised various conceptualisations and operationalisations of realism. Content analysis was then conducted on this data, through frequency counts of dimensions of realism listed in each paper as well as an analysis of dimensional structure of realism in different disciplines.

3. RESULTS

With the sample of 85 papers content analysis was conducted to collect dimensions of realism identified in the literature. Fifty-five dimensions of realism were identified (see Table 1). While realism was commonly defined as a multi-dimensional construct (e.g. Cho et al., 2011; Gao, 2016; Nabi et al., 2006), 29 of the included papers measured, discussed or listed only one dimension of "realism" (see Figure 1). This was particularly noteworthy for Social Science papers. A sample quotes below illustrates a unidimensional operationalisation of realism.

"*Subjective realism of the virtual characters and sexual attraction elicited by the virtual characters were assessed with a six point Likert scale ranging from 0 (not at all realistic/ not at all sexually attractive) to 5 (very realistic / very sexually attractive) while looking at the virtual characters*" (Fromberger et al., 2015, p. 9)

Dimensions of realism were often discussed in terms of specificity and objects of realism. Specificity refers to the idea that appraisals can be made about the realism of TV in general, or about an individual show, or even more specifically, about a specific storyline within a show (Konijn et al., 2009). The object of realism refers to the way in which appraisals can be targeted at different features such as character emotions, social situations, individual characters and different places in a mediated representation (Eilders & Nitsch 2015). Some papers debated whether realism could be on a continuum (from more to less realistic) or a dichotomy (real or fake) (R. W. Busselle, 2001; Cho et al., 2011; Eilders & Nitsch, 2015). Two papers conceptualized "levels of realism", referring to the level of realism needed for the virtual environment to be *authentic* (Chalmers & Ferko, 2010; Kowalczyk & Royne, 2012).

Dimensionality was evident in VR papers, where, for example, *photo realism* was often broken down to *geometric realism* and *illumination realism* (e.g. Slater et al., 2009). Similarly, *Anthropomorphism* or *virtual agent realism* included dimensions of *appearance* and *behaviour* (e.g. Kwon et al., 2013). *Fidelity* was commonly examined in VR and can be defined as how much the simulation bears resemblance to real life, this includes dimensions of scenario or *simulation fidelity*, *display fidelity* and *interactive fidelity*. Dimensionality was also evident in many TV papers that referenced one or more of Hall's (2003) dimensions: *factuality*, *plausibility*, *typicality*, *involvement*, *narrative consistency* and *perceptual persuasiveness* (Cho et al., 2011; Dhoest, 2007; Ward & Carlson, 2013). Overall the most prevalent dimensions of realism throughout our included literature were *photorealism* (17 papers), *perceived similarity to real life* (16 papers), *social realism* (16 papers) and *typicality* (11 papers).

Table 1. Dimensions of Realism *List of dimensions of realism identified across our sample of media literature. Dimensions are defined and the "count" refers to how many of the included papers referred to this dimension.*

Dimension	Description	Count
Visual realism/photorealism	Realism measurable through visual quality of TV program / VR simulation	17
Perceived similarity to real life	Realism as a judgement of how similar media content is to real life/real world.	16
Social realism	How similar people and events are to real world.	16
Differentiation between perceived / subjective realism and objective realism	Differentiations between perceived realism of the viewer and realism of the technology/media.	11
Typicality/Probability	How likely is this to happen in the real world?	11
Realism of agent/anthropomorphism	Realism of virtual agent in VR simulation	10
Possibility/Plausibility	Could this happen in the real world?	9
Magic Window Realism	Children's understanding that characters are not inside the TV.	7
Realism of characters	Perceived realism in characters in media representation	7
Interactivity	Realistic if it allows for interactivity	6
Behavioural realism of virtual character/agent	Realism measurable through behaviour of character/agent in VR simulation	5
Appearance of agent/virtual human	Dimension of anthropomorphism	5
Gritty realism	Showing darker aspects of stories and characters, enhancing perceived realism	4
Physical realism	Does the virtual environment behave as it should / would in real life?	4
Functional/behavioural realism	Where you can do things, you could do in real life in a virtual environment	4
Behaviour of agent/virtual human	Dimension of anthropomorphism	4
Fidelity	How much simulation bears resemblance to real life	4
Mundane daily activities	Daily activities that are recognisable to audience act as a type of realism	3
Involvement	Involvement with characters or portrayals	3
Narrative consistency	Coherency of narrative	3
Emotional realism	Realism of represented emotions	3
Scenario/simulation fidelity	Closeness of simulation to real life behaviours, rules and object properties	3
Display fidelity	Reproduction of real-world sensory stimuli by display system	3
Interactive fidelity	Reproduction of real-world interactions	3
Formal Realism	How much representation looks like real-life	2
Thematic Realism	How close what the representation is about matches real life.	2
Timeliness	How "up to date" representation.	2
Historical/Socio-Political Realism	Blending of recent socio political into narrative.	2
Ordinariness	Elements of every-day life increase realism	2

Table 1. Contd.

Dimension	Description	Count
Capitalist Realism	Construction of realism using details of economic reality of living in a capitalist society	2
There reality/experiential realism	Realism where viewers feel they are actually there	2
Magical realism	Juxtaposition of something magical or outrageous happening within a more real life setting.	2
Reality TV authenticity	Perceived realism of reality TV program	2
Geometric realism	Virtual object looks like real life object	2
Illumination realism	Fidelity of lighting model	2
Believable realism	Unrealistic if it looks too pristine to be real life.	2
Geo-cultural realism	Parallels with local history and culture	1
Austerity Realism	Presenting the reality that there are no alternatives to cuts and self-reliance	1
Narrative probability	Narratives use of "good reasons"	1
Sense of reality	Sense that a mediated object is real / belongs to the real world	1
Realism as social cognition	Social realism as a type of social cognition	1
Cast eccentricity	Uniqueness of cast	1
Representativeness	Representativeness of	1
Producer manipulation	Perceived level of producer interference in reality tv narrative	1
Candidness	Perceived honesty of cast	1
Believability	Was representation believable?	1
Parodic realism	Realistic because it parodies elements of real life.	1
Cartoon realism	Paradox – not real people but still realistic	1
Cognitive realism	Realistic problem-solving processes	1
Scene realism	Connectedness and continuity of the stimuli being experienced	1
Meaningfulness	Meaningfulness of experience is an element of realism	1
Sound realism	Realism of auditory stimuli being experienced	1
Environmental realism	Visual and sound realism together	1

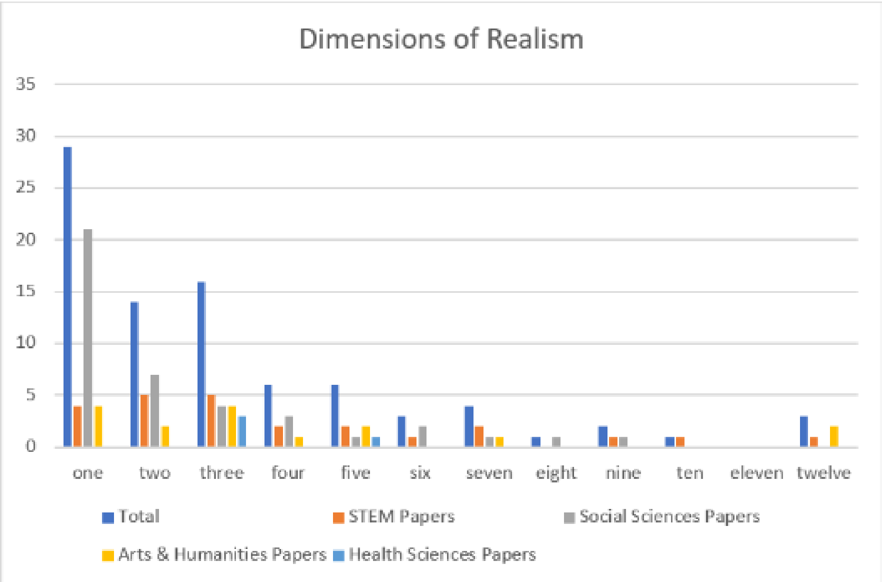


Figure 1. *This figure depicts the number of dimensions referred to in the included papers. The x axis represents the number of dimensions listed, defined or measure. The y axis represents the number of papers which included this dimensionality in their conceptualisation or operationalisation of realism. Papers are represented by total, and by discipline.*

4. DISCUSSION

There has long been consensus in media theory that perceived realism is a multi-dimensional construct (Busselle & Greenberg, 2000; Hawkins, 1977), grounded in the idea that judgements or perceived reality of media cannot be unidimensional when reality is not unidimensional. Our findings reflect this, with 53 different dimensions of realism identified across our sample of media literature. Many of these dimensions pertained to an objective conceptualisation of realism – realism as a feature of the technology or media rather than a subjective property of the media user. For example within VR papers realism was often focused on through *fidelity* or *photorealism*. We recommend future research explore the relationship between such objectively realistic features of technology (visual quality, narrative elements etc.) and subjective or perceived realism (psychological experience of realism)

Despite the aforementioned consensus of multi-dimensional perceived realism and the many theorised dimensions, our findings indicate that many studies across media literature continue to operationalise or conceptualise realism in a unidimensional way. This was particularly noteworthy within Social Science papers. Measurement of perceived reality as a unidimensional construct often occurred through single item self report measures consisting of some variation of "how real was this to you?". Not all self report measures were problematic, for example presence subscales focused which included realism questions pertaining to both the feelings of the user and judgments of the appearance of the media. To reflect the multi-dimensional nature of perceived reality self report measures should not be single item, and we recommend future researchers take a more innovative approach to measurement.

As previous literature has noted, the most common dimensions of subjective or perceived realism examined in media literature were *plausibility/possibility, typicality/probability* as well as *social realism* and *perceived similarity to real life* (Dorr, 1983; Hall, 2003). These dimensions pertain to an evaluation of "relative realism" (Rooney & Hennessy, 2013), a comparison of the stimulus to real life based on one's experiences and expectations. Less commonly examined were dimensions corresponding to apparent reality, or the extent of illusion of non-mediation (Rooney et al., 2012; Rooney & Hennessy, 2013). Media users can perceive an apparent reality during engagement where there is minimal or no awareness of mediation. This is in direct contrast to dimensions of relative realism which involve clear awareness of mediation - one cannot compare a representation to reality, without distinguishing between reality and the representation. This discrepancy between empirical focus on these two categories or domains of perceived realism dimensions was first noted by Hall (2003) and our findings confirm that this remains the case – at least within our sample of media literature. We recommend future research further explore apparent reality. This can be done with self report measures using dimensions such as *involvement* or *perceptual persuasiveness*, or it can be achieved with measures focusing on the in-the-moment "online" experience of perceived reality of media such as continuous or behavioural measures and physiological measures.

Our findings support theory – realism is multi-dimensional and integral to interaction with media and virtual technologies. Capturing complex multi-dimensional subjective experiences of realism requires a holistic, innovative approach to measures. We recommend future research explore the relationship between subjective experiences of realism (psychological experience of realism) and objective realistic features of technology (visual quality, narrative elements etc.) and further consider how to measure the "online" experience of perceived apparent reality. This scoping review can assist researchers and scholars across different disciplines in guiding further realism research.

5. CONCLUSION

We have conducted a systematic scoping review of realism literature across multiple disciplines and report that despite the multidimensionality of realism as a construct, many studies continue to conceptualise and operationalise realism in simplistic unidimensional ways with researchers often use single dimensional, self-report methods. We recommend that future research utilise multiple methods such as "in the moment" online measures and psychophysiological measures to capture the holistic nature of perceived realism. This approach may help address the imbalance in empirical studies which tend to focus on dimensions of relative realism (comparison to real life) judgments rather than dimensions of apparent realism (perceiving as real during media engagement).

5. REFERENCES

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Bouchard, S., Dumoulin, S., Talbot, J., Ledoux, A. A., Phillips, J., Monthuy-Blanc, J., Labonté-Chartrand, G., Robillard, G., Cantamesse, M., & Renaud, P. (2012). Manipulating subjective realism and its impact on presence: Preliminary results on feasibility and neuroanatomical correlates. *Interacting with Computers*, *24*(4), 227–236. https://doi.org/10.1016/j.intcom.2012.04.011

Busselle, R., & Bilandzic, H. (2008). Fictionality and perceived realism in experiencing stories: A model of narrative comprehension and engagement. *Communication Theory*, *18*(2), 255–280. https://doi.org/10.1111/j.1468-2885.2008.00322.x

Busselle, R., & Greenberg, B. S. (2000). The Nature of Television Realism Judgments: A Reevaluation of Their Conceptualization and Measurement. *Mass Communication and Society*, *3*(2–3), 249–268. https://doi.org/10.1207/s15327825mcs0323_05

Busselle, R. W. (2001). Television Exposure, Perceived Realism, and Exemplar Accessibility in the Social Judgment Process. *Media Psychology*, *3*(1), 43–67. https://doi.org/10.1207/S1532785XMEP0301_03

Cho, H., Wilson, K., & Choi, J. (2011). Perceived realism of television medical dramas and perceptions about physicians. *Journal of Media Psychology*, *23*(3), 141–148. https://doi.org/10.1027/1864-1105/a000047

Dhoest, A. (2007). Identifying with the nation: Viewer memories of Flemish TV fiction. *European Journal of Cultural Studies*, *10*(1), 55–73. https://doi.org/10.1177/1367549407072970

Dorr, A. (1983). No shortcuts to judging reality. In *Bryant & D. R. Anderson (Eds.), Children's understanding of television: Research on attention and comprehension* (pp. 199–220). Academic Press.

Eilders, C., & Nitsch, C. (2015). Politics in fictional entertainment: An empirical classification of movies and TV series. *International Journal of Communication*, *9*(1), 1563–1587.

Fromberger, P., Meyer, S., Kempf, C., Jordan, K., & Müller, J. L. (2015). Virtual viewing time: The relationship between presence and sexual interest in androphilic and gynephilic men. *PLoS ONE*, *10*(5), 1–28. https://doi.org/10.1371/journal.pone.0127156

Gao, Y. (2016). Fiction as reality: Chinese youths watching American television. In *Poetics* (Vol. 54, pp. 1–13). https://doi.org/10.1016/j.poetic.2015.08.005

Hall, A. (2003). Reading Realism: Audiences' Evaluations. *Journal of Communication*, *December*, 624–641.

Hawkins, R. P. (1977). The Dimensional Structure of Children's Perceptions of Television Reality. *Communication Research*, *4*(3), 299–320. https://doi.org/10.1177/009365027700400304

Kisker, J., Gruber, T., & Schöne, B. (2019). Behavioral realism and lifelike psychophysiological responses in virtual reality by the example of a height exposure. *Psychological Research*. https://doi.org/10.1007/s00426-019-01244-9

Konijn, E. A., Van Der Molen, J. H. W., & Van Nes, S. (2009). Emotions bias perceptions of realism in audiovisual media: Why we may take fiction for real. *Discourse Processes*, *46*(4), 309–340. https://doi.org/10.1080/01638530902728546

Kwon, J. H., Powell, J., & Chalmers, A. (2013). How level of realism influences anxiety in virtual reality environments for a job interview. *International Journal of Human Computer Studies*, *71*(10), 978–987. https://doi.org/10.1016/j.ijhcs.2013.07.003

Levac, D., Colquhoun, H., & O'Brien, K. K. (2010). Scoping studies: advancing the methodology. *Implementation Science*, *5*(1), 69. https://doi.org/10.1186/1748-5908-5-69

Lombard, M., & Ditton, T. (1997). At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication*, *3*(2), 0–0. https://doi.org/10.1111/j.1083-6101.1997.tb00072.x

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*, *339*(jul21 1), b2535–b2535. https://doi.org/10.1136/bmj.b2535

Nabi, R. L., Stitt, C. R., Halford, J., & Finnerty, K. L. (2006). Emotional and Cognitive Predictors of the Enjoyment of Reality-Based and Fictional Television Programming: An Elaboration of the Uses and Gratifications Perspective. *Media Psychology*, *8*(4), 421–447. https://doi.org/10.1207/s1532785xmep0804_5

Rooney, B., Benson, C., & Hennessy, E. (2012). The apparent reality of movies and emotional arousal: A study using physiological and self-report measures. *Poetics*, *40*(5). https://doi.org/10.1016/j.poetic.2012.07.004

Rooney, B., & Hennessy, E. (2013). Actually in the Cinema: A Field Study Comparing Real 3D and 2D Movie Patrons' Attention, Emotion, and Film Satisfaction. *Media Psychology*, *16*(4). https://doi.org/10.1080/15213269.2013.838905

Shapiro, M. A., & Makana Chock, T. (2003). Psychological processes in perceiving reality. In *Media Psychology* (Vol. 5, Issue 2, pp. 163–198). Lawrence Erlbaum Associates Inc. https://doi.org/10.1207/S1532785XMEP0502_3

Slater, M., Gonzalez-Liencres, C., Haggard, P., Vinkers, C., Gregory-Clarke, R., Jelley, S., Watson, Z., Breen, G., Schwarz, R., Steptoe, W., Szostak, D., Halan, S., Fox, D., & Silver, J. (2020). The Ethics of Realism in Virtual and Augmented Reality. *Frontiers in Virtual Reality*, *1*(March), 1–13. https://doi.org/10.3389/frvir.2020.00001

Slater, M., Khanna, P., Mortensen, J., & Yu, I. (2009). Visual realism enhances realistic response in an immersive virtual environment. *IEEE Computer Graphics and Applications*, *29*(3), 76–84. https://doi.org/10.1109/MCG.2009.55

Tan, E. S. H. (2008). Entertainment is emotion: The functional architecture of the entertainment experience. *Media Psychology*, *11*(1), 28–51. https://doi.org/10.1080/15213260701853161

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology*, *8*(1), 45. https://doi.org/10.1186/1471-2288-8-45

Ward, L. M., & Carlson, C. (2013). Modeling Meanness: Associations Between Reality TV Consumption, Perceived Realism, and Adolescents' Social Aggression. *Media Psychology*, *16*(4), 371–389. https://doi.org/10.1080/15213269.2013.832627

Development of Cooperative Assistive Technology User Experience Evaluation Model for Blind and Visually Impaired People

Sami Pohjolainen[1], Babar Chaudary[2], Leena Arhippainen[3], Petri Pulli[2]

[1,2]OASIS Research Group, [3]INTERACT Research Group, Information Technology and Electrical Engineering Faculty, University of Oulu, PL 8000, FI-90014, Oulu, FINLAND

[1]*sami.pohjolainen@gmail.com*, [2]*babar.chaudary@oulu.fi*, [3]*leena.arhippainen@oulu.fi*, [2]*petri.pulli@oulu.fi*

[1,2,3]*www.oulu.fi*

ABSTRACT

Blind and visually impaired people are among those who require very specific types of assistive technology. This type of technology has been a research and development focus for decades. As technology has matured, more affordable and practical solutions have entered the market. Unfortunately, this has not resulted in a very positive trend in terms of acceptance or adoption. Our research on usability and user experience indicated that there is a need to extend standardized questionnaires when evaluating assistive technology. This paper details the development of an evaluation model with extended contexts that can be used with cooperative assistive technology aimed for blind or visually impaired people and their caretakers. We present our evaluation setting and procedure for the model. The development of the model is based on testing, literature review, expert interviews, and discussions. The extended contexts should also contribute towards the trend of modularity with standardized user experience questionnaires.

1. INTRODUCTION

Those who suffer from visual impairments face major challenges to their daily life, as they suffer from adverse effects to their performance in many situations (Bhatlawande et al, 2014). Projections show that there were around 38.5 million blind and 237.1 million people with moderate or severe visual impairment in 2020. These are expected to triple to 114.6 million and 587.6 million by 2050, respectively. This means that a significantly higher number of people will need Assistive Technologies (AT) in the future. (Bourne et al, 2017). Improving mobility and navigation of Blind and Visually Impaired People (VIP) has and continues to be one of the main areas of research and development focus when it comes to AT. This is reflected with the fact that an important societal goal is to help VIP remain independent and integrated to the society, which in turn will improve their quality of life. (Calder, 2009; Bohwmick and Hazarika, 2017.)

The problem with AT in general has been that people with disabilities are not keen to adopt them and discontinuance rates tend to be high. While there are VIP who use the latest technology to help them in various tasks, research has shown that many barriers and reasons still exist why the acceptance for these technologies is so low. (Riemer-Reiss and Wacker, 2000; Roentgen et al, 2008; Paajala and Keränen, 2015; Gori et al, 2016.) Developing products for VIP is a continuing challenge. Developers themselves have generally reported positive results from end users when testing new technologies (Bhatlawande et al, 2014). However, according to Roentgen et al. (2008) many these products fail to meet the needs of visually impaired. Calder (2009) and Riemer-Reiss et al. (2000) outline difficulties of designing AT products with a lasting effect to the market, as it is hard to match user requirements of a constantly evolving ecosystem of products and VIP who can often have multiple disabilities and very specific needs. Varity of technology, such as type of sensors used, also add to challenge of development AT with longevity, as advances in technology can make even proven solutions either obsolete or undesirable. A good example of this is the arrival of affordable smartphones. (Roentgen et al, 2008; Islam et al, 2019.)

The research for this paper started with a need to evaluate usability and User eXperience (UX) of a new AT, which was a prototype level system of an Electronic Travel Aid (ETA) developed for VIP (Chaudary et al, 2020).

A unique aspect of this system is that it relies on cooperation between users. It has a multimodal interface that works over the internet of things (IoT) relying on both haptic and vocal communication. Caretakers, which can include friends and family, use an application on a device that shows them the field of view of the VIP through smartphone camera that is placed on the chest of the VIP. Users can communicate vocally, but navigational assistance is mainly provided through haptic feedback to the white cane using a simple set of vibrations. In a case where the primary caretaker is unfamiliar with the area, they can request help from another caretaker, who can in-turn help the VIP to navigate through that. Our initial strategy was to use a standardized UX questionnaire for the evaluation and chose meCUE 2.0 from Minge and Thüring (2018). Testing was done with several VIP who carried out navigational tasks with the system and completed questionnaires along with interviews. This gave us valuable insight (Chaudary et al, 2020). However, further research in the topics of usability and UX revealed that it would be prudent to extend our evaluation methods to capture more holistic understanding of specific needs and issues related to VIP and their caretakers. For example, the use of the system relies on cooperation of two or more people, so it was important for us to capture the impact that has on UX of all users.

This paper represents an extended usability and UX evaluation model that is suitable for a cooperative AT intended for VIP and their caretakers. The paper is organized, as follows. Section 2 discusses the related research on ETA for VIP, and usability and UX evaluations in general. Section 3 introduces our research model including extended contexts for VIP and describes the evaluation setting and procedure. Section 4 concludes the paper.

2. RELATED WORK

The first part of this section looks at the research related to AT for VIP. In the second part, focus is on usability and UX evaluation methods focusing on standardized questionnaires and additional UX evaluation contexts.

2.1 Electronic Travel Aids for Blind and Visually Impaired

VIP mainly use two kinds of AT: primary and secondary. Primary technology includes more widely adopted products such as the traditional white cane. Secondary technology consists of many product categories and includes ETA to help VIP with navigation and with sensing of the near environment (Loomis et al, 2007; Cardillo and Cademi, 2019). Islam et al. (2019) divide ETA into three categories of sensor-, computer vision- and smartphone-based. According to Islam et al. (2019) all categories have been very active in terms of product development, so there is a lot choice and variety. Today many VIP also own a standard smartphone and can use variety of apps, such as BlindSquare, RightHear and Be My Eyes that also supplement their needs (Avila et al, 2016; Be My Eyes, n.d.; BlindSquare, n.d.; RightHear, n.d.).

The truth is that there have been many barriers that have inhibited the adoption of ETA. The products used to be cumbersome, unreliable, expensive, and not widely available (Roentgen et al, 2008; Kim and Cho, 2013). Ongoing miniaturization, maturity and rapid advancements of technology, availability and lower costs have removed many of these barriers (Cardillo and Cademi, 2019). Another problem is that majority of VIP are elderly and often have other cognitive and physical disabilities. According to Ojamo (2018) estimated 69 percent of VIP in Finland are at least 65 years old or older and 57 percent are 75 years old or older. Elderly tend to be laggards in adoption of new technologies, but emerging young-elderly are showing much higher adoption rates (Mostaghel, 2016). Research also indicates that younger people with disabilities are more willing to experiment with AT, as they are often very goal and task orientated, and look to improve independence and performance (Ripat and Woodgate, 2017).

Roentgen et al. (2012) mention that individual needs and preferences are important factors determining the adoption and the use of ETA over time. Other factors that can act either as facilitators or barriers included goals and expectations, requirements, functions, functionalities, features of the product, and also environmental factors. Research shows that many VIP are also willing to collaborate and communicate with other people when completing navigation or orientation related tasks (Balata et al, 2012, 2014). The Be My Eyes application is a good example of volunteer community-based AT that helps VIPs and is used widely (Be My Eyes, n.d.).

2.2 Usability and User Experience

For the purpose of this research, ISO 9241-210 (ISO, 2010) provides adequate definitions to both usability and UX. Essentially UX is defined, as "*A person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service*" (ISO, 2010). UX includes, for instance, "*user's emotions, beliefs, preferences, perceptions, behaviours, psychological and physical responses that can occur before, during and after the use*".

It is also "*a consequence of brand image, presentation, functionality, system performance, interactive behaviour and assistive capabilities of the interactive system, the user's internal and physical state resulting from prior experience, attitudes, skills and personality, and the context of use*". In addition, usability is defined as "*the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments*". (ISO, 2010.) There are many valid definitions for UX besides the given one, Bevan (2009) explains that different interpretations of UX can lead to different scopes and measures, while different emphasis on usability or UX can lead to different concerns. Vermeeren et al. (2010) are of an opinion that usability and UX are intervened and that UX subsumes usability. Arhippainen (2009) sees usability as an interaction experience that is surrounded by different contexts that contribute to the overall UX through the interaction. Both Arhippainen (2009) and Vermeeren et al. (2010) indicate that UX evaluation methods should be augmented with usability dimension.

Research also show that it is important to capture UX over time, as views on UX tend to change as time passes. Feng and Wei (2019) differentiate between first-time and long-term UX. Those product qualities that provided positive initial experience may not be those motiving for longer use. Familiarity, functional dependency, and emotional attachment are the main temporal forces that impact the experience over time. (Marti and Iacono, 2016; Karapanos et al, 2009). Roto et al. (2011) suggest four time periods when to capture UX. These are: Anticipated UX before the usage, Momentary UX while experience the use, Episodic UX when reflecting on the experience and finally Cumulative UX when recollecting memories from multiple periods of use. Evaluation methods for each period can be quite different. Standardized UX questionnaires can be used to capture at least Episodic UX and Cumulative UX (Marti and Iacono, 2016).

There are many usability and UX methods in the market that can be used to evaluate variety products from different angles (Chung and Sahari, 2015). Some of the methods are free to use, while other require payment. Since last decade, few standardized UX questionnaires have emerged. AttrakDiff, UEQ and meCUE are currently used in academic research and Diaz-Oreiro et al. (2019) provided a systematic literature review for them. They noted that by far the most popular is AttrakDiff, as it was first to the market in 2003. However, UEQ has surpassed it in 2017 and 2018, while MeCUE remains a relative newcomer. The benefit of using standardized questionnaire is that they are easy to use and economical, while considered reliable and valid measuring methods. However, Diaz-Oreiro et al. (2019) conclude that in over sixty percent of the cases between one and five additional methods were used to complement a standardized questionnaire. SUS (System Usability Scale), a standardized usability questionnaire introduced by Brooke in 1996, was used often.

AttrakDiff (Hassenzahl et al, 2003) and meCUE (Minge and Thüring, 2017) both evaluate hedonic and pragmatic dimensions of UX. In addition, meCUE considers emotional dimension and has a wider perspective on acceptance. MeCUE is also a modular approach to a standardized UX questionnaire. It is currently more comprehensive than AttrakDiff because it was developed with the latest research in mind. The purpose was to make a single standardized questionnaire that would address key components of UX (Minge and Thüring, 2017). MeCUE questionnaire is now on its second incarnation and has four modules that focus on different UX dimensions. First two modules focus on perception of instrumental and non-instrumental qualities, respectively. The third module is about emotions and the fourth module focuses on consequences of use. The fifth module is used for overall evaluation. While the questionnaire is comprehensive, it is still missing certain aspects of UX. Missing dimensions include perceptions of acoustic and haptic quality, and trustworthiness of the system and received information. In addition, the questionnaire focuses on interaction with a technical device and does not consider interpersonal relations and social influences of UX. (Minge and Thüring, 2018.)

Additionally, we identified several UX contexts from research that would be suitable for VIP and collaborative situations. These contexts were either missing or only partially implemented in standardized questionnaires. Starting with the issue of trust. Forster et al (2018) show that trust is an important precursor of for acceptance of technology. Petrie and Bevan (2009) consider safety and trust from usability perspective. They are concerned whether the system safety is about protecting the user or whether the user trusts the system to behave as intended. Schrepp and Thomaschewski (2019), when validating additional scales for UEQ, consider trust from more safety perspective and have dependability as a separate scale measuring trust in a similar manner defined by Petrie and Bevan (2009). UEQ+ is more recent version and a modular approach to UEQ (UEQ+, n.d.). The questionnaire introduces several new scales that are relevant measures for AT. Trustworthiness of content, haptics, acoustics, and adaptability of the product are measures that can provide insight to VIP using AT. (Schrepp and Thomaschewski, 2019). In addition, Arhippainen (2009) presents several additional contexts that are missing from many current usability and UX evaluation methods. These include social, physical and culture contexts. The culture context is about the habits and rules the user has, but also habits and rules of others, and even differences between people from different countries. Social contexts are essentially about presence of other people, sharing the experience, and having to deal with distractions, such as phone calls during the interaction of the product. Physical contexts focus on environment itself where the interaction takes place. It can include aspects such as weather or differences between indoor and outdoor lighting. (Schilit, 1995; Arhippainen, 2009.)

3. CAT UX EVALUTION MODEL FOR VIP

This section focuses on the development process of our UX evaluation model. The CAT UX Evaluation Model for VIP *(Cooperative Assistive Technology User Experience Evaluation Model for Blind and Visually Impaired People)* is shown in Figure 1. The dotted lines represent methods developed by other authors (Brooke, 1996; Roto et al, 2011; Minge and Thüring, 2018). Our main contribution is the Extended Contexts. These contexts are explained in more detail. We also give an example of our evaluation setting and procedure for its use.

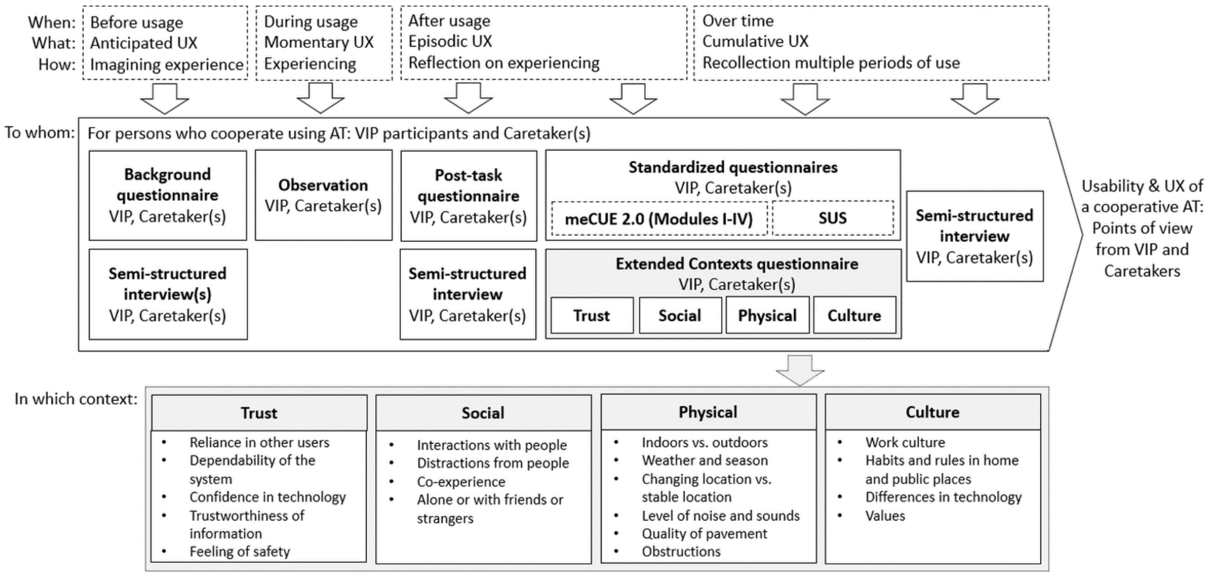


Figure 1. *The CAT UX Evaluation Model for VIP*

After our initial evaluation of the prototype system with meCUE 2.0 questionnaire (Minge and Thüring, 2018), we came to conclusion that a more holistic perspective might benefit the further development of the system (Chaudary et al, 2020). This meant evaluating both VIP and caretaker's perspectives in more detail. Karapanos et al. (2009) make clear that time is a significant factor on how users experience and evaluate systems. This led us to incorporate periods of experience into the evaluation model, as described by Roto et al. (2011). In addition, Minge and Thüring (2018) explain that their questionnaire intends to be an efficient, but not a comprehensive, method of capturing key aspects of UX. As it is a common practice to supplement standardized questionnaires, we started to look for other suitable methods (Diaz-Oreiro et al, 2019). Usability was identified, as one of the important issues that was not covered in detail by meCUE 2.0. To rectify this, we decided to add the SUS (Brooke, 1996) model, as it is widely used in academia and industry, and has proven to be both reliable and valid (Brooke, 2013). We also identified several other factors specific to AT intended for VIP and their caretakers. These were categorised under four Extended Contexts: Trust, Social, Physical and Culture.

Findings from the literature review and our interviews with experts lead us to develop several extended contexts to capture aspects that were not presented in more standardized UX questionnaires. The factors in each context were chosen because they were associated with UX of VIP or a part of social UX with their caretakers. Extended Contexts (Fig. 1) were implemented in a separate questionnaire. Each factor in a context extends the questionnaire with 2-4 additional questions. These contexts could be expanded further, but we made a choice between specificity rather than comprehensiveness. It was also considered that there was a need to limit the number of factors to avoid too many items in the questionnaire.

3.1 Trust, Social, Physical and Culture contexts

Trust context is concerned with the trust between the users and whether they have trust in the system itself. Forster et al. (2018) show trust as a separate from user UX and refer to the method develop Jian et al. (2000) that is often used to measure trust between people and systems. They consider trust, as prerequisite for acceptance of technology. While this is the case, we consider trust from the UX perspective and present it here more as a category of similar items rather than as a measure. However, thematically the context does group similar items together that try to answer specific questions related to trust or confidence.

It was important to understand, if VIP feels that they can safely use the system to navigate from one location to another or whether a caretaker thinks that the system is dependable enough to help them guide VIP in their destination. We also wanted to know whether the users felt safe using the system and how much confidence they had in technology employed. The system should also feel dependable and trustworthy. So that VIP does not stumble on obstacles because of delays in communication or turn in a wrong direction when receiving information. Trustworthiness of information and dependability of the system are similar described by Schrepp and Thomaschewski (2019).

Schilit (1995) identified three environmental categories that impact the interaction of a product. The first two deal with social conditions, such as being alone or with others and changing social situation. The third one is about physical environment where the interaction occurs. Nicólas and Aurisicchio (2011) explained that five types of contexts are often mentioned in research: physical, social, cultural, situational, and temporal. In this study, we decided to use three separate contexts: social, physical, and cultural. Temporal is presented with periods of experience (Roto et al, 2011), while we felt that the situational context did not apply with our evaluation needs. However, understanding UX differences with work and leisure activities or between goal- and action-mode should be included when necessary.

Social context is about differences when experiencing an interaction with products in the presence of others or alone (Nicólas and Aurisicchio, 2011). Interactions with people and various social distractions can have significant effect on UX. Battarbee and Koskinen (2004) observed that people create, elaborate and evaluate experiences together with other people and that this UX can be different from that they would have alone. Co-experience aims to capture important interactions and collaborations between people, as a part of expanding UX evaluation.

Physical context deals with UX in the physical environment and when there is change in locale. Traditionally computers were used in rather unchanging office environment, but this has changed significantly with mobile mobility (Schilit, 1995). Physical environment can hamper the use of a product. For example, the quality of pavement or many obstructions can make it difficult for VIP to traverse the terrain. Noises and sounds can reduce the user attention on the product. Weather conditions and different seasons can change the UX considerably. In addition, things like the level of lighting or temperature might make it difficult to use a product and therefore make the use experience worse. (Forlizzi, 2008; Nicólas and Aurisicchio, 2011.)

Culture context is about users having different backgrounds, values, habits, and rules that can influence the UX of a product. According to Ripat and Woodgate (2011) some AT users may identify with a disability culture that can contain a shared set of beliefs, values, and behaviours. While users have their own habits and rules, it is important to consider the larger view that considers differences between work or organizational cultures, current level and availability of technology in a country, what type of products are favoured, and more general acceptance products in culture or sub-culture. (Arhippainen, 2009; Nicólas and Aurisicchio, 2011.)

3.2 Evaluation setting and procedure

The evaluation setting and procedure is shown in Figure 2. This is an example that is loosely based on our own requirements. Each evaluation consists of three participants. Participant 1 and 2 are interacting with the system for the first time. Participant 3 can be somewhat familiar with the situation and the system but knows the location particularly well and therefore acts as a location expert. Participants are familiarized with the system and then complete two navigational tasks. Variety of methods is used to capture different aspects of UX at specific points of the evaluation. Data is collected from all participants, as shown in Figure 2. The other methods, such as semi-structured interviews, were selected, as they were suitable for this test setting.

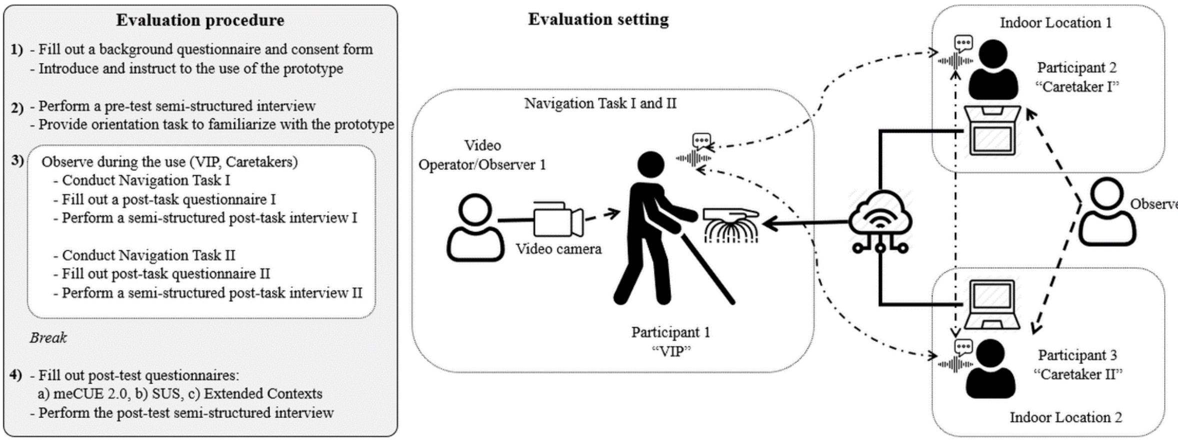


Figure 2. *The Evaluation Setting and Procedure*

4. CONCLUSIONS

This paper presents The CAT UX Evaluation Model for VIP (Cooperative Assistive Technology User Experience Evaluation Model for Blind and Visually Impaired People). This model can be used as an example on how to evaluate AT with VIP. It is suitable for prototype systems and can be adapted to evaluate AT in the market. The original plan was to validate the evaluation model in March and layout those findings also in this paper, but because of Covid-19, we were unable to conduct the required tests. The evaluation setting and procedure we describe in the paper should be considered as an example. It is how we wanted to capture more holistic evaluation of UX in this very specific setting. We acknowledge the fact that longer evaluation in a real-life, might capture even more temporal issues than a short testing session and should be pursued when possible.

In future, there will be significantly more people who suffer from blindness or visual impairments who require AT to function in a society. It should be noted that significant differences exist on how well visual impairment and its related issues have been handled in different regions of the world. This impacts the availability of AT and supporting technology. Regardless, there have been many attempts to develop AT for VIP, but these have not been widely adopted. The only notable exception to this is the low-tech, but popular White Cane, which is widely in use and has not been replaced with newer solutions even though there have been many attempts. As technology has matured, we expect to see many more attempts to create good AT for people with various disabilities. When it comes to AT for VIP, one development related problem seems to be with the evaluation of prototypes. Evaluations often seems to incorporate standardized methods but fail to consider other contexts related to VIP. This has resulted in very positive evaluations, which is not reflected in the actual adoption or continued use of AT. Our Extended Contexts highlights several important and specific factors related to UX of VIP. These additional contexts can be used to supplement standardized methods, such as meCUE 2.0 and SUS. We feel that this also contributes towards the trend of modularity in standardized UX questionnaires, as it allows evaluators to design their own questionnaires by choosing which modules to include depending on a specific context. We believe that modularity should be explored further. Our model and its Extended Contexts would benefit from further validation.

5. REFERENCES

Arhippainen, L. (2009). Studying user experience: issues and problems of mobile services–Case ADAMOS: User experience (im)possible to catch? University of Oulu. Department of Information Processing Science (Doctoral dissertation, Doctoral thesis), 218-221.

Avila, M., Wolf, K., Brock, A. & Henze, N. (2016). Remote Assistance for Blind Users in Daily Life: A Survey about Be My Eyes. 1-2. 10.1145/2910674.2935839.

Balata, J., Míkovec, Z., & Slavík, P. (2012). Mutual communication in navigation of visually impaired. In *2012 IEEE 3rd International Conference on Cognitive Infocommunications* (CogInfoCom) (pp. 769-774). IEEE.

Balata, J., Franc, J., Mikovec, Z., & Slavik, P. (2014). Collaborative navigation of visually impaired. *Journal on Multimodal User Interfaces*, 8(2), 175-185.

Battarbee, K., & Koskinen, I. (2005). Co-experience: user experience as interaction. CoDesign, 1(1), 5-18.

Be My Eyes. (n.d.). Retrieved May 29, 2020, from Be My Eyes website: https://www.bemyeyes.com/

Bevan, N. (2009). What is the difference between the purpose of usability and user experience evaluation methods. In *Proceedings of the Workshop UXEM* (Vol. 9, pp. 1-4).

Bhatlawande, S., Mahadevappa, M., Mukherjee, J., Biswas, M., Das, D., & Gupta, S. (2014). Design, development, and clinical evaluation of the electronic mobility cane for vision rehabilitation. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 22(6), 1148-1159.

Bhowmick, A., & Hazarika, S. M. (2017). An insight into assistive technology for the visually impaired and blind people: state-of-the-art and future trends. *Journal on Multimodal User Interfaces*, 11(2), 149-172.

BlindSquare. (n.d.). Retrieved May 29, 2020, from BlindSquare website: https://www.blindsquare.com/

Bourne, R. R., Flaxman, S. R., Braithwaite, T., Cicinelli, M. V., Das, A., Jonas, J. B., ... & Naidoo, K. (2017). Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *The Lancet Global Health*, 5(9), e888-e897

Brooke, J. (1996). SUS-A quick and dirty usability scale. Usability evaluation in industry, 189(194), 4-7.

Brooke, J. (2013). SUS: a retrospective. Journal of usability studies, 8(2), 29-40.

Calder, D. J. (2009). Travel aids for the blind-The digital ecosystem solution. In 2009 *7th IEEE International Conference on Industrial Informatics* (pp. 149-154). IEEE.

Cardillo, E., & Caddemi, A. (2019). Insight on Electronic Travel Aids for Visually Impaired People: A Review on the Electromagnetic Technology. Electronics, 8(11), 1281.

Chaudary, B., Pohjolainen, S., Aziz, S., Arhippainen, L. & Pulli, P. (2020) Tele-guidance based Remote Navigation Assistance for Visually Impaired and Blind People – Development and User Experience Findings. Submitted to 13th ICDVRAT with ITAG, Serpa, Portugal 8–10 Sept. 2021.

Chung, T. K., & Sahari, N. (2015). Utilitarian or experiential? An analysis of usability questionnaires. International Journal of Computer Theory and Engineering, 7(2), 167-171.

Díaz-Oreiro, I., López, G., Quesada, L. & Guerrero, L. A. (2019). Standardized Questionnaires for User Experience Evaluation: A Systematic Literature Review. *Proceedings*, 31(1), p. 14. doi:10.3390/proceedings2019031014

Feng, L., & Wei, W. (2019). An Empirical Study on User Experience Evaluation and Identification of Critical UX Issues. *Sustainability*, 11(8), 2432.

Forlizzi, J. (2008). The product ecology: Understanding social product use and supporting design culture. International Journal of design, 2(1).

Forster, Y., Hergeth, S., Naujoks, F., & Krems, J. F. (2018). How Usability Can Save the Day-Methodological Considerations for Making Automated Driving a Success Story. In Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 278-290).

Gori, M., Cappagli, G., Tonelli, A., Baud-Bovy, G., & Finocchietti, S. (2016). Devices for visually impaired people: High technological devices with low user acceptance and no adaptability for children. *Neuroscience & Biobehavioral Reviews*, 69, 79-88.

Hassenzahl, M., Burmester, M., & Koller, F. (2003). AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In *Mensch & computer* 2003 (pp. 187-196). Vieweg+ Teubner Verlag.

Islam, M. M., Sadi, M. S., Zamli, K. Z., & Ahmed, M. M. (2019). Developing walking assistants for visually impaired people: A review. *IEEE Sensors Journal*, 19(8), 2814-2828.

ISO. (2010). ISO 9241-210 Ergonomics of human-system interaction - Part 210: Human-centred design for interactive systems. Geneva: International Standardization Organization (ISO).

Jian, J. Y., Bisantz, A. M., & Drury, C. G. (2000). Foundations for an empirically determined scale of trust in automated systems. *International journal of cognitive ergonomics*, 4(1), 53-71.

Karapanos, E., Zimmerman, J., Forlizzi, J., & Martens, J. B. (2009). User experience over time: an initial framework. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 729-738).

Kim, S. Y., & Cho, K. (2013). Usability and design guidelines of smart canes for users with visual impairments. *International Journal of Design*, 7(1).

Loomis, J. M., Golledge, R. G., Klatzky, R. L., & Marston, J. R. (2007). Assisting Wayfinding in Visually Impaired Travelers. In G. L. Allen (Ed.), *Applied spatial cognition: From research to cognitive technology* (p. 179–202). Lawrence Erlbaum Associates Publishers.

Marti, P., & Iacono, I. (2016). Anticipated, momentary, episodic, remembered: the many facets of User eXperience. In *2016 Federated Conference on Computer Science and Information Systems* (FedCSIS) (pp. 1647-1655). IEEE.

Minge, M., Thüring, M., Wagner, I., & Kuhr, C. V. (2017). The meCUE questionnaire: a modular tool for measuring user experience. In *Advances in Ergonomics Modeling, Usability & Special Populations* (pp. 115-128). Springer, Cham.

Minge, M., & Thüring, M. (2018). The meCUE questionnaire (2.0): Meeting five basic requirements for lean and standardized UX assessment. In *International Conference of Design, User Experience, and Usability* (pp. 451-469). Springer, Cham.

Mostaghel, R. (2016). Innovation and technology for the elderly: Systematic literature review. *Journal of Business Research*, 69(11), pp. 4896-4900. doi:10.1016/j.jbusres.2016.04.049

Nicólas, J. O., & Aurisicchio, M. (2011). The scenario of user experience. In SJ Culley, BJ Hicks, TC McAloone, TJ Howard, and P. Badke-Schaub, In *Proceedings of the 18th International Conference on Engineering Design* (ICED 11) (pp. 182-193).

Ojamo, M. (2018) The Finnish Register of Visual Impairment: Annual Statistics 2018

Paajala, I. J., & Keränen, N. (2015). Study for acceptance on new navigation assistance by visually impaired people. In *2015 9th International Symposium on Medical Information and Communication Technology* (ISMICT) (pp. 64-67). IEEE.

Petrie, H., & Bevan, N. (2009). The Evaluation of Accessibility, Usability, and User Experience. *The universal access handbook*, 1, 1-16.

Riemer-Reiss, M. L., & Wacker, R. R. (2000). Factors associated with assistive technology discontinuance among individuals with disabilities. *Journal of Rehabilitation*, 66(3).

RightHear. (n.d.). Retrieved May 29, 2020, from RightHear website: https://www.right-hear.com//

Ripat, J. & Woodgate, R. (2011). The intersection of culture, disability and assistive technology. *Disability and Rehabilitation: Assistive Technology*, 6(2), pp. 87-96. doi:10.3109/17483107.2010.507859

Ripat, J. D., & Woodgate, R. L. (2017). The importance of assistive technology in the productivity pursuits of young adults with disabilities. Work, 57(4), 455-468.

Roentgen, U. R., Gelderblom, G. J., Soede, M., & De Witte, L. P. (2008). Inventory of electronic mobility aids for persons with visual impairments: A literature review. *Journal of Visual Impairment & Blindness*, 102(11), 702-724.

Roentgen, U. R., Gelderblom, G. J., & de Witte, L. P. (2012). User evaluation of two electronic mobility aids for persons who are visually impaired: a quasi-experimental study using a standardized mobility course. Assistive Technology, 24(2), 110-120.

Roto, V., Law, E., Vermeeren, A., & Hoonhout, J. (2011). User Experience White Paper. Outcome of the Dagstuhl Seminar on Demarcating User Experience, Germany.

Schilit, W. N. (1995). A system architecture for context-aware molbil computing (Doctoral dissertation, Columbia University)

Schrepp, M. & Thomaschewski, J. (2019). Construction and first Validation of Extension Scales for the User Experience Questionnaire (UEQ). 10.13140/RG.2.2.19260.08325.

UEQ+. (n.d.). Retrieved May 29, 2020, from UEQ+ website: http://ueqplus.ueq-research.org/

Vermeeren, A. P., Law, E. L. C., Roto, V., Obrist, M., Hoonhout, J., & Väänänen-Vainio-Mattila, K. (2010, October). User experience evaluation methods: current state and development needs. In *Proceedings of the 6th Nordic conference on human-computer interaction: Extending boundaries*, pp. 521-530.

Virtual reality online therapy (VROT): Development of a multipurpose application for psychological intervention

F Dias[1], P Gamito[2], T Souto[3]

[1,2]HEI-Lab: Digital Human-environment Interaction Lab, University Lusófona, Lisbon, PORTUGAL

[1,2]Faculty of Psychology and Life Sciences, University Lusófona, Lisbon, PORTUGAL

[3]Faculty of Psychology, Sports and Education, University Lusófona of Oporto, Porto, PORTUGAL

[1]*fabio.dias@ulusofona.pt*, [2]*pedro.gamito@ulusofona.pt*, [3]*p2683@ulp.pt*

[1,2]*www.hei-lab.ulusofona.pt*, [1,2]*www.ulusofona.pt*, [3]*www.ulp.pt*

ABSTRACT

Virtual reality (VR) has consistently proven its effectiveness as a tool for psychological intervention over the past decades. Continuous technological breakthroughs have allowed its graduation from a simple gadget to a full-blown medium, giving birth to new and unique ways of delivering therapy at a distance. By relocating therapy into a virtual online office, this article aims to delineate an application that will provide a robust framework for further expanding existing knowledge in cybertherapy. Initial pilot studies are currently planned to evaluate potential use-cases and to explore avatars as embodied entities of users in a multi-user clinical context.

Keywords Cybertherapy, Online Therapy, Virtual Reality Therapy, Avatar

1. INTRODUCTION

The integration of technology in clinical psychology has continuously brought new contributions to the field, from introducing new digital interventions to promoting global dissemination of services (Fairburn & Patel, 2017). While online delivered services can potentially reduce costs and increase their accessibility (Ebert et al., 2018), local digital interventions, specifically those performed with virtual reality (VR) have consistently proven their effectiveness as a viable clinical tool (Cipresso et al., 2018; Riva et al., 2019; Rizzo & Koenig, 2017).

Implementing VR interventions in an online format has the potential to revolutionise online therapy and help promote widespread adoption of VR in mental health (Wiederhold, 2018). A recent systematic review on multi-user VR interventions revealed that the first steps have been taken in this path, but much is yet to be explored (Dias, 2021). In this article we'll discuss a possible way forward, delineating a centralised application for researching and to effectively implement this empirical knowledge in the field.

1.1 VR in Psychotherapy

VR is a technology which allows a user to interact with computer-generated immersive environments. These virtual environments (VEs) can be experienced through a variety of systems, from a simple monitor and keyboard setup to positional tracking head-mounted displays (HMDs). Riva and collaborators (2019) proposed that HMD-based immersive systems utilise a similar mechanism used by our brains - embodied simulations. According to this model, VR simulates the external reality of the user, and through virtual interaction (which requires the same bodily processes: visceral/ autonomic, motor, and sensorial information), it facilitates cognitive modulation. These immersive systems offer a possibility to: (a) simulate the real world in a controlled environment (Parsons, 2014); (b) trigger physical and psychological responses similar to the real world through immersion and presence (Diemer et al., 2015); (c) intervene in the moment, presenting an unique option for psychotherapists (Park et al., 2019); and (d) generalize virtual learnings into the real world (Schultheis & Rizzo, 2001).

Brahnam and Jain (2011) listed four commonly used intervention techniques using VR: virtual reality exposure therapy (VRET); virtual cue exposure therapy; body image modification through avatars; and pain distraction. VRET is the most commonly used technique (Maples-Keller et al., 2017), however, there are a number of other possibilities. In 2008, Freeman suggested seven purposes for VR in psychosis: symptom assessment; establishing symptom correlates; identifying predictive variables, differential predictors, and environmental predictors; establishing causal factors; and developing new treatments. These purposes are also relevant to all fields of mental health, although some have been largely neglected and most report small sample sizes (Freeman et al., 2017).

From a practical perspective, several disorders share common characteristics, and VR provides an excellent gateway for confrontation in a controlled environment (Park et al., 2019). This can be done through mediation of a trained practitioner, often in the same physical room, or even automated (Freeman et al., 2018). VR capabilities greatly expand when paired with psychophysiological readings, not only providing access to more objective data (Côté & Bouchard, 2005), but also allowing interventions via biofeedback (Pallavicini et al., 2009) and neurofeedback (Cho et al., 2004).

1.2 Advantages and limitations of online VR interventions

The first major selling point of online interventions is accessibility, as reducing the distance between therapists and clients promotes a more convenient way to access services, solving issues such as lack of mobility, time constraints, coverage of rural regions, access to specialized experts, confidentiality, and language or cultural barriers (Andersson & Titov, 2014). A recent report from the European Federation of Psychologists' Associations concludes that internet and mobile based interventions have a high level of applicability, being overall cost-effective as a standalone therapy in routine conditions, while also potentially helpful in improving effectiveness of face-to-face services when used in tandem (Ebert et al., 2018).

The scarcity of non-verbal elements accounts for some constraints on therapist adherence to online modalities, as non-verbal communication is still considered central to the therapeutic relationship (Barak et al., 2008). The establishment of a therapeutic alliance is one of the key-factors associated with effectiveness of psychological interventions, nonetheless, it appears to be comparable between face-to-face and remote modalities, even in the absence of some visual and auditory elements (Pihlaja et al., 2018). The use of avatars in VEs could potentially fill some of the gaps in online communication (Baccon et al., 2019), while also making it possible to use techniques based on embodiment (Kilteni et al., 2012) and to promote therapeutic adherence (Knaevelsrud & Maercker, 2006).

In what regards the effectiveness of VR interventions, a recent meta-review reported positive results for assessment and treatment on over 25 meta-analyses, systematic and narrative reviews for a broad variety of disorders (anxiety, eating and weight, autism spectrum and other neurodevelopmental disorders, psychosis and pain management) (Riva et al., 2019). According to Rizzo and Koenig (2017), more comprehensive guidelines for a safe and ethical use of VR in professional practice are still lacking. Although this technology has its own peculiarities to take into account (Slater et al., 2020), several existing guidelines for online digital practices are also applicable for VR psychotherapy (Haberstroh et al., 2014). However, cybersickness - symptoms of motion sickness caused by artificial images in motion (Laviola Jr., 2000), is still a valid concern. These symptoms may be minimized with repetitive exposure (Gavgani et al., 2016) or by changing the movement mode with the provision of interoceptive cues (Bouchard et al., 2011).

In terms of its most common use-case, Fernández-Álvarez et al. (2020) conducted an analysis on anxiety disorder interventions through VR over the past decade and found several changes in attitudes, preferences and perceptions of VR as a clinical tool for both therapists and clients, namely: (a) the preference of customers in VEs versus *in vivo* exposure; (b) a positive change in the therapists' attitude towards VR; (c) similar results in terms of the therapeutic alliance; (d) drop-out rates identical to face-to-face modalities; (e) possible increase in adherence through greater involvement with the VE; (f) possible increase in effectiveness through different mechanisms of change (e.g. different scenarios); and (g) stability of results at follow-up.

HMD devices have become increasingly more accessible over the past years (Roche et al., 2019). Considering the increasing user adoption, the effectiveness of VR therapy, and existing technology for multiplayer networking, all that's left is a deeper scientific exploration of VR, not only as a tool, but as a medium in mental health.

2. PROPOSED METHOD

2.1 *Application Outline and Functionalities*

VROT is an application that aims to provide a framework for exploring and deepen existing knowledge of VR centred therapeutic approaches in a single application. Currently in a very early stage of development, its core features aim to include: (a) single and multi-user connectivity; (b) different immersive levels with both PC and PCVR compatibility; (c) a character creation system; (d) platform adapted graphics, animacy and interactions; (e) procedural generated environments; and lastly (f) therapy aid tools.

This application is currently being developed at HEI-Lab (University Lusófona) by the main author. The development process started in late 2019 under Unity 3D, initially targeting low-end VR through smartphones for increased accessibility. With feedback from pre-tests regarding the technical limitations of this platform, and given the multiple COVID related confinements that prevented further testing, the application is being revamped under the Unreal game engine with added functionalities.

2.1.1 Connectivity. While the peer-to-peer multi-user option is one of the application's main valences, the learning outcomes of trials will contribute to the development of autonomous tools, such as taking part of guided exercises with a non-playable character in-between therapy sessions. The single player option will also enable its use in a more conventional local setting, presenting a safe option for feature testing and validating different environments and tools before adding distance as a potential variable. Even in a local setting, the online functionality is still a requirement given the need to track app access and user data in a clinical context.

2.1.2 Immersivity level. One of the initial considerations when choosing a platform (i.e., using a computer screen with keyboard and mouse or HMDs with controllers) is their inherent immersive capabilities. This concern was raised by therapists specifically due to eye fatigue of HMDs when performing multiple sessions and also to enable use of non-digital resources during sessions (e.g., notetaking). Although not using HMD's will limit the level of animacy of the displayed avatar, it may help boost the app's dissemination in contexts where immersiveness isn't a strict requirement for the client and/or therapist, further raising the importance of inquiring about the impact of physical immersion in a variety of use-cases.

2.1.3 Character creation. Full body human avatars are used both by playable characters and non-player characters (NPCs). Clients and therapists can select and customise their own avatar, which is then linked to their username inside the application. Customisation options consist of simple tick boxes and sliders with currently 74 head morphs, 8 body morphs, 25 total clothing items, and 14 total hairstyles (Fig. 1). This system presents a level of personification that potentially enables tools such as embodiment, role-switching and out-of-body experiences.

Figure 1. *Character creation and example models.*

2.1.4 Platform scalability. HMDs with 6-DoF (degrees of freedom) remotes utilise inverse kinematics to simulate upper body movements based on head and hands position. In the case of lower-end systems, avatars do not replicate the movements performed. Instead, they have pre-defined idle and movement animations to simulate body expressions when sitting, standing and moving. Regarding facial expressions, avatars randomly perform certain actions (such as blinking), while some other facial features are replicated based on real-time speech capture. Eye gaze is based on the proximity to another avatar, although therapists may influence the NPCs look target. Interaction with motion controllers is made primordially through joysticks and hand collisions, while mouse and keyboard focus instead on point-and-click and key presses. The implemented art style focus on high fidelity realism for a greater resemblance to the real world, although graphical settings may be adjusted to adapt to the device's capabilities.

2.1.5 Environments. The initial iteration of this application consists of a pre-built virtual office, city street and metro (Fig. 2). Other scenes are also currently planned, namely: group room, relaxation environment, airport, airplane, apartment, public bathroom, auditorium, restaurant, and highway. While some of these scenes have clear use-cases (e.g., airplane for fear of flying), others will present more holistic options (e.g., walking through the apartment and exploring clients' activities of daily living (ADLs)). Since these scenes are built with modular assets, the planned addition of procedural generation will provide therapists with a seed system for customising the dimensions and themes of each level, thus providing a higher degree of tailoring to fit their clients' needs.

Figure 2. *Scenes currently included in the application (from left to right: virtual office, city street, metro).*

2.1.5 Tools. Each scene has a variety of attributes that can be manipulated at any given time by the therapist (e.g., number of NPCs and associated behaviour, weather, dirtiness, turbulence). Custom tools are also in development to enable richer and more dynamic experiences, such as: real-time physiological response monitorization, whiteboards, virtual diaries, triggered crowd events, runtime perspective switch, time stop, and single-player mode with self-guided exercises. Each of these and other features will be validated separately to avoid contamination and feature-creep.

2.2 Data Collection

There are four sources of data available for analysis: paper and pencil questionnaires; application logs, containing interaction inputs for each user; psychophysiological data; and video recording of the therapist's screen. Beyond their clinical purpose, this data set may be used for a variety of different cases, such as: help assess the advantages and limitations of the experimental conditions based on the devices and target group; train future practitioners in the field of cybertherapy; and to improve the application functionalities. Given data privacy concerns, each user undergoes an authentication process when loading the app. While therapists may request to follow each of his/her clients' data, only the lead researchers have access to the full database.

Video recordings, collected with consent from both parts, will be crucial to better understand the app usage and to help train future therapists. The paper and pencil instruments may vary greatly depending on the goal and target group of each study, although with some commonalities: a sociodemographic and digital competences questionnaire is collected at the beginning; and a psychological battery is administered pre and post therapeutic intervention. A follow-up including general symptom evaluation will also be scheduled for the majority of the underlying studies. A cybersickness questionnaire will be answered at the end of each immersive session, along with a working alliance inventory and a short session feedback questionnaire.

The application outputs a file containing a variety of logs: session number; therapist and client reference codes; devices used; application version number; date; start and end time; time spent on each scene; and both client and therapist input per each scene (type and amount). Therapist screen recordings contains audio and video data from the therapist's window (which may include the client(s) first person view, should the therapist decide to enable this option). Psychophysiological data will vary with the use-case, consisting mostly of heart rate and skin conductance readings, being the two most used physiological assessments in VEs due to their ability to capture several immersion facets and anxiety levels (Martinez et al., 2020).

2.3 Procedures

Given the scope of this application, two main study topics are currently envisioned: (1) assessment of functionalities, and (2) VR online psychotherapy.

2.3.1 Assessment of functionalities. These set of studies aim to validate the general usability of the application's core and secondary features. One of the initial pilot studies will consist in analysing the therapeutic alliance through avatars using different devices (using a laptop screen or a HMD with motion controllers). The target population will consist of university students with on-site scheduled psychological counselling sessions. Other studies done by HEI-Lab that explore VR tools (e.g., avatar-based relaxation, ACT metaphors in VR) may also be adapted and integrated to VROT, later to be validated in a more clinical context.

2.3.2 VR online psychotherapy. Two pilot studies are planned for individual therapy in panic disorder and obsessive-compulsive disorders. Therapy sessions are done on-site instead of remotely to insure a controlled testing environment and due to hospital safety policy. However, therapist and client will remain in separate divisions (to allow building a working alliance based on avatars and to maintain social distance. The appointments result from referral procedures for specialized consultations at Lisbon's Psychiatric Hospital (CHPL) Cognitive Behavioural Therapy (CBT) Unit. Each scenario and tool will be validated by a panel of experts belonging to CHPL, and each therapist is free to establish their own CBT treatment protocol. Control groups are based on treatment as usual at CHPL, consisting of group sessions for panic disorder and individual interventions for obsessive-compulsive disorder.

If the clients demonstrate interest in participating, an appointment for psychological assessment, avatar creation, and familiarization with VR is scheduled. The client is then introduced to an assistant responsible for the supervision of sessions, psychological assessments, and management of virtual and psychophysiology equipment. Sessions are conducted inside the VEs online, lasting on average 30 minutes. Remotes may be used for virtual movement and interactions, while some techniques, such as walking in place, will be explained if the client expresses symptoms of motion sickness. Each client will be given an informed consent pertaining the confidentiality of information collected and anonymity. It also highlights that the client may voluntarily, and at any time, end it or change to a more traditional intervention. These studies will be submitted to the Ethics and Deontology Commission for scientific research at CHPL and the Faculty of Psychology and Life Sciences at University Lusófona, strictly following the General Data Protection Regulation (GDPR), directive 95/46/EC (Regulation (EU), 2016).

2.4 Improving the Application

Although this application was developed to address the current post-pandemic needs of field practitioners, centring all these functionalities under a single application will provide a more controlled framework for research, while also facilitating the integration of new scenes (e.g., doctor's office for trypanophobia) and tools (e.g., virtual art therapy). Several of the included tools will derive from a direct transposition of traditional CBT techniques into VR, although a feasible alternative consists in designing assessment and treatment methods unique to this medium (Linder et al, 2019). These additions are thought to provide innovative solutions for monitorization in-between sessions and even self-guided interventions (Donker et al., 2019). It may also be relevant to introduce several gamification components (e.g., quests, scoring systems) to increase motivation and encourage task repetition (Linder et al., 2020; Sailer et al., 2017).

3. CONCLUSIONS

The use of VR as an online-based intervention could allow both modalities to overcome some of the limitations and flaws inherent to both (e.g., diagnostic errors in online media, low accessibility of VR interventions), while also providing a great platform for research and innovation for VR within psychology (Wiederhold & Riva, 2019). Avatars present a strong option to help mediate online interventions in a VE (Rehm et al., 2016), although more research is needed to access several aspects of this intervention dynamic.

Several pilot studies will help assess the viability of this application as a new way for field practitioners and researchers to utilise VR in mental health, allowing greater liberty for the development and dissemination of VR interventions, while also providing a tailored tool in response to arising global needs.

Acknowledgement: This study is funded by the Foundation for Science and Technology – FCT (Portuguese Ministry of Science, Technology and Higher Education), under the grant UIDB/05380/2020.

4. REFERENCES

Andersson, G, and Titov, N, (2014), Advantages and limitations of Internet-based interventions for common mental disorders. *World Psychiatry*, **13**, *1*, pp. 4–11. https://doi.org/10.1002/wps.20083

Baccon, LA, Chiarovano, E, and MacDougall, HG, (2019), Virtual reality for teletherapy: Avatars may combine the benefits of face-to-face communication with the anonymity of online text-based communication, *Cyberpsychology, Behavior, and Social Networking*, **22**, *2*, pp. 158–165. https://doi.org/10.1089/cyber.2018.0247

Barak, A, Hen, L, Boniel-Nissim, M, and Shapira, N, (2008), A comprehensive review and a meta-analysis of the effectiveness of internet-based psychotherapeutic interventions, *Journal of Technology in Human Services*, **26**, *2–4*, pp. 109–160. https://doi.org/10.1080/15228830802094429

Bouchard, S, Robillard, G, Renaud, P, and Bernier, F, (2011), Exploring new dimensions in the assessment of virtual reality induced side effects, *Journal of Computer and Information Technology*, **1**, pp. 20–32. http://w3.uqo.ca/cyberpsy/wp-content/uploads/2019/04/2011ssq.pdf

Brahnam S, and Jain LC, (2011), *Advanced Computational Intelligence Paradigms in Healthcare 6: Virtual reality in psychotherapy, rehabilitation, and assessment*, Studies in Computational Intelligence, Berlin: Springer. https://doi.org/10.1007/978-3-642-17824-5

Cho, B-H, Kim, S, Shin, DI, Lee, JH, Min Lee, S, Young Kim, I, and Kim, SI, (2004), Neurofeedback training with virtual reality for inattention and impulsiveness, *CyberPsychology & Behavior*, **7**, *5*, pp. 519–526. https://doi.org/10.1089/cpb.2004.7.519

Cipresso, P, Giglioli, IAC, Raya, MA, and Riva, G, (2018), The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature, *Frontiers in Psychology*, **9**. https://doi.org/10.3389/fpsyg.2018.02086

Côté, S, and Bouchard, S, (2005), Documenting the efficacy of virtual reality exposure with psychophysiological and Information processing measures, *Appl Psychophysiol Biofeedback*, **30**, *3*, 217–232. https://doi.org/10.1007/s10484-005-6379-x

Dias, F, (2021), *Terapia online através de realidade virtual: Revisão sistemática e proposta de aplicação*, [Master's thesis, University Lusófona], ReCiL. http://hdl.handle.net/10437/11980

Diemer, J, Alpers, GW, Peperkorn, HM, Shiban, Y, and Mühlberger, A, (2015), The impact of perception and presence on emotional reactions: A review of research in virtual reality, *Frontiers in Psychology*, **6**, 26. https://doi.org/10.3389/fpsyg.2015.00026

Donker, T, Cornelisz I, van Klaveren, C, van Straten, A, Carlbring, P, Cujipers, P, and van Gelder, J-L, (2019), Effectiveness of self-guided app-based virtual reality cognitive behavior therapy for acrophobia: A randomized clinical trial, *JAMA Psychiatry*, **76**, *7*, pp. 682–690. https://doi.org/10.1001/jamapsychiatry.2019.0219

Ebert, DD, van Daele, T, Nordgreen, T, Karekla, M, Compare, A, Zarbo, C, Brugnera, A, Oeverland, S, Baumeister, H, and Taylor, J, (2018), Internet and mobile-based psychological interventions: Applications, efficacy, and potential for improving mental health, *European Psychologist*, **23**, pp. 167–187. https://doi.org/10.1027/1016-9040/a000318

Fairburn, CG, and Patel, V, (2017), The impact of digital technology on psychological treatments and their dissemination, *Behaviour Research and Therapy*, **88**, pp. 19–25. https://doi.org/10.1016/j.brat.2016.08.012

Fernández-Álvarez, J, Di Lernia, D, and Riva, G, (2020), Virtual reality for anxiety disorders: Rethinking a field in expansion, In Y-K Kim (Ed), *Anxiety Disorders: Rethinking and Understanding Recent Discoveries*, pp. 389–414, South Korea: Springer. https://doi.org/10.1007/978-981-32-9705-0_21

Freeman, D, (2008), Studying and treating schizophrenia using virtual reality: A new paradigm, *Schizophrenia Bulletin*, **34**, *4*, pp. 605–610. https://doi.org/10.1093/schbul/sbn020

Freeman, D, Haselton, P, Freeman, J, Spanlang, B, Kishore, S, Albery, E, Denne, M, Brown, P, Slater, M, and Nickless, A, (2018), Automated psychological therapy using immersive virtual reality for treatment of fear of heights: A single-blind, parallel-group, randomised controlled trial, *The Lancet Psychiatry*, **5**, *8*, pp. 625–632. https://doi.org/10.1016/S2215-0366(18)30226-8

Freeman, D, Reeve, S, Robinson, A, Ehlers, A, Clark, D, Spanlang, B, and Slater, M, (2017), Virtual reality in the assessment, understanding, and treatment of mental health disorders, *Psychological Medicine*, **47**, *14*, pp. 2393–2400. https://doi.org/10.1017/s003329171700040x

Gavgani, AM, Nesbitt, KV, Blackmore, KL, and Nalivaiko, E, (2016), Profiling subjective symptoms and autonomic changes associated with cybersickness, *Autonomic Neuroscience*, **203**, pp. 41–50. https://doi.org/10.1016/j.autneu.2016.12.004

Haberstroh, S, Barney, L, Foster, N, and Duffey, T, (2014), The ethical and legal practice of online counselling and psychotherapy: A review of mental health professions, *Journal of Technology in Human Services*, **32**, *3*, pp. 149–157. https://doi.org/10.1080/15228835.2013.872074

Kilteni, K, Groten, R, and Slater, M, (2012), The sense of embodiment in virtual reality, *Presence: Teleoperators and Virtual Environments*, **21**, *4*, pp. 373–387. https://doi.org/10.1162/pres_a_00124

Knaevelsrud, C, and Maercker, A, (2006), Does the quality of the working alliance predict treatment outcome in online psychotherapy for traumatized patients?, *J Med Internet Res*, **8**, *4*, pp. 31. https://doi.org/10.2196/jmir.8.4.e31

LaViola, Jr, (2000), A discussion of cybersickness in virtual environments, *ACM SIGCHI Bulletin*, **32**, pp. 47–56. https://doi.org/10.1145/333329.333344

Lindner, P, Hamilton, W, Miloff, A, and Carlbring, P, (2019), How to treat depression with low-intensity virtual reality interventions: perspectives on translating cognitive behavioral techniques into the virtual reality modality and how to make anti-depressive use of virtual reality-unique experiences, *Frontiers in psychiatry*, **10**, *792*. https://doi.org/10.3389/fpsyt.2019.00792

Lindner, P, Miloff, A, Bergman, C, Andersson, G, Hamilton, W, and Carlbring, P, (2020), Gamified, automated virtual reality exposure therapy for fear of spiders: A single-subject trial under simulated real-world conditions, *Frontiers in psychiatry*, **11**, *116*. https://doi.org/10.3389/fpsyt.2020.00116

Maples-Keller, JL, Bunnell, BE, Kim, S-J, and Rothbaum, BO, (2017), The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders, *Harvard Review of Psychiatry*, **25**, *3*, pp. 103–113. https://doi.org/10.1097/hrp.0000000000000138

Martinez, M, Arbelaez, G, Dupont, L, Hily, A, Camargo, M, Jacob, C, and Dinet, J, (2020), Physiological assessment of user experience supported by immersive environments: first input from a literature review, *ConVRgence (VRIC) Virtual Reality International Conference Proceedings*, pp. 89–99. https://doi.org/10.20870/IJVR.2020...3316

Pallavicini, F, Algeri, D, Repetto C, Gorini A, and Riva, G, (2009), Biofeedback, virtual reality and mobile phones in the treatment of generalized anxiety disorder (gad): A phase-2 controlled clinical trial, *Journal of CyberTherapy & Rehabilitation*, **2**, *4*, pp. 315–327.

Park, MJ, Kim, DJ, Lee, U, Na, EJ, and Jeon, HJ, (2019). A literature overview of virtual reality (vr) in treatment of psychiatric disorders: Recent advances and limitations, *Frontiers in Psychiatry*, **10**. https://doi.org/10.3389/fpsyt.2019.00505

Parsons, TD, (2014), Virtual teacher and classroom for assessment of neurodevelopmental disorders, In *Serious Games, Alternative Realities, and Play Therapy* (S Brahnam & LC Jain, Eds), Germany: Springer-Verlag, pp. 121–137. https://doi.org/10.1007/978-3-642-45432-5_7

Pihlaja, S, Stenberg, J-H, Joutsenniemi, K, Mehik, H, Ritola, V, and Joffe, G, (2018), Therapeutic alliance in guided internet therapy programs for depression and anxiety disorders: A systematic review, *Internet Interventions*, **11**, pp. 1–10. https://doi.org/10.1016/j.invent.2017.11.005

Regulation (EU), (2016), 2016/679 of the European parliament and of the council of 27 of April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), *Official Journal of the European Union*, **119**, pp.1–88. http://data.europa.eu/eli/reg/2016/679/oj

Rehm, IC, Foenander, E, Wallace, K, Abbott, J-AM, Kyrios, M, and Thomas, N, (2016), What role can avatars play in e-mental health interventions? Exploring new models of client–therapist interaction, *Frontiers in Psychiatry*, **7**. https://doi.org/10.3389/fpsyt.2016.00186

Riva, G, Wiederhold, BK, and Mantovani, F, (2019), Neuroscience of virtual reality: From virtual exposure to embodied medicine, *Cyberpsychology, Behavior, and Social Networking*, **22**, *1*, pp. 82–96. https://doi.org/10.1089/cyber.2017.29099.gri

Rizzo, A, and Koenig, S, (2017), Is clinical virtual reality ready for primetime?, *Neuropsychology*, **31**, 8, pp. 877–899. https://doi.org/10.1037/neu0000405

Roche, K, Chawla, S, Liu, S, and Siegel, S, (2019), The effects of virtual reality on mental wellness: A literature review, *Journal of Neurology, Psychiatry and Brain Research*, **1**, pp. 1–8. http://mhfmjournal.com/pdf/the-effects-of-virtual-reality-on-mental-wellness-a-literature-review.pdf

Sailer, M, Hense, JU, Mayr, SK, and Mandl, H, (2017), How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction, *Computers in Human Behavior*, **69**, pp.371–380. https://doi.org/10.1016/j.chb.2016.12.033

Schultheis, MT, and Rizzo, AA, (2001), The application of virtual reality technology in rehabilitation, *Rehabilitation Psychology*, **46**, *3*, pp. 296–311. https://doi.org/10.1037/0090-5550.46.3.296

Slater, M, Gonzalez-Liencres, C, Haggard, P, Vinkers, C, Gregory-Clarke, R, Jelley, S, Watson, Z, Breen, G, Schwarz, R, Steptoe, W, Szostak, D, Halan, S, Fox, DL, and Silver, JD, (2020), The Ethics of Realism in Virtual and Augmented Reality, *Frontiers in Virtual Reality*, **1**, *1*. https://doi.org/10.3389/frvir.2020.00001

Wiederhold, BK, (2018), Are we ready for online virtual reality therapy?, *Cyberpsychology, Behavior, and Social Networking*, **21**, pp. 341–342. https://doi.org/10.1089/cyber.2018.29114.bkw

Wiederhold, BK, and Riva, G, (2019), Virtual reality therapy: Emerging topics and future challenges. Cyberpsychology, Behavior, and Social Networking, **22**, *1*, pp. 3–6. https://doi.org/10.1089/cyber.2018.29136.bkw

Emotional Carousel: A Novel System for Emotional Regulation

Bruno Patrão[1], Gustavo Assunção[2], Paulo Menezes[3], Nuno Gonçalves[4], Paula Castilho[5]

[1,2,3,4] University of Coimbra, Institute of Systems and Robotics,
R. Sílvio Lima, 3030-290 Coimbra, PORTUGAL

[5] University of Coimbra, Faculty of Psychology and Education Sciences,
R. Colégio Novo, 3000-115 Coimbra, PORTUGAL

[1]bpatrao@isr.uc.pt, [2]gustavo.assuncao@isr.uc.pt, [3]paulomenezes@isr.uc.pt,

[4]nunogon@deec.uc.pt, [5]paulacastilho@fpce.uc.pt

ABSTRACT

In this paper we propose a system for emotion regulation directed towards, but not limited to, virtual reality exposure-based therapies. Our approach is based on emotional state recognition and consequent deliverance of specific stimuli which will drive the regulation process. The main goal of the system is to aid therapists, as a tool during exposure therapy procedures, providing real time emotional state classification and information on the impact of the delivered stimuli. Furthermore, the system is intended to be autonomous in that it routes its own user feedback content path, instantiated by a list of goal emotional states provided by the therapist in charge. The system is based on a control loop model where the therapist provides the desired emotional state to be induced, after exposing the patient to the stimuli, the system analyses the patient physiological responses, face and postures features to estimate the manifested emotional state. The stimuli are delivered through augmented reality, virtual reality or imagery, enabling the user to be guided through emotional stimulation. To assess the current emotional states which may trigger the employed stimuli generation mechanism, we built a recurrent neural network which receives as input corresponding physiological and visual features. The recurrent nature of the model accounts for the temporal correlations in the data, enabling an evolutionary evaluation, classifying it in terms of valence, arousal and dominance. As for its training phase contextualised data was used, which pertains to a set of participants performing specific tasks which trigger specific emotional activations. These include short videos, games and scripting which guide the users through various types of emotional situations.

1. INTRODUCTION

As emotions have substantial influence on cognitive processes of humans such as learning, memory, perception and problem solving, they influence the way people interact with the world, other people, and naturally with technology. Emotional interactions may be explored and exploit to the benefit of different applications. Conversely technological solutions are being used since long to induce emotional states, as is the case of cinema and videogames. This can further be relevant in modern healthcare especially in the application with patients suffering from psychological and emotional difficulties. To this end, psychotherapy applications guiding patients through their mental rehabilitation while adapting to the patient emotional state, would be highly motivating and might lead to faster recovery. Some authors state that emotions are the result of the dynamic interaction between cognition (or perceptions), behaviours (or action tendencies) and physiological responses [Mauss et al., 2005]. Furthermore, they emerge primarily out of automatic, stimulus-driven responses and permit a greater role for controlled, cognitive processes and behaviours. Being an integrated and coordinated response of the entire body system, the main function of emotions is to quickly change and adapt the behavioural reaction in order to achieve the individual's valued goals in a particular situation [Gross, 1999]. Based on this, the biological and physiological expression of emotions may be explored as anchors for emotion recognition.

In general, emotion recognition methods may be classified into two major categories, those that analyse external behaviour signs and internal body signals. The first category includes signs such as facial expression, speech, gesture, posture. However, the reliability cannot be guaranteed, as it is relatively easy for people to control those physical signals like facial expression or speech to omit their real emotions especially during social situations. For example, people might express a smile in a social conversation even if they are in a negative emotional state. The other category is the internal physiological signals, which include the electrical activity at the brain, heart, muscular level, body temperature, electrodermal activity, and breathing patterns and rates. These signals are regulated by the human nervous system, which is divided into two parts: the central and the peripheral nervous systems (CNS and PNS). The PNS consists of the autonomic and the somatic nervous systems (ANS and SNS). According to Porges [2011], there is a link between emotion manifestation and the autonomic nervous system (ANS). The physiological signals are in response to the CNS and the ANS of the human body, in which emotion changes. One of the major benefits of accessing these physiological signals is that the CNS and the ANS are largely involuntarily activated and therefore cannot be easily controlled. Furthermore, these involuntary responses produce signal patterns that can be measured.

Although there are different models proposed to describe emotions, one of the most used is based on three components arousal, valence, and dominance. The arousal dimension is used to quantify different degrees from calm to excitement levels while the valence dimension indicates whether human feelings are positive or negative and the dominance dimension is related to feelings of control and the extent to which an individual feel restricted in his behaviours [Koelstra et al., 2012]. This decomposition is especially useful to label and establish a parametrisation of the emotional related physiological patterns. In order to acquire and use contextualised physiological data for emotion recognition, a controlled environment for emotion induction should be guaranteed. A good approach to achieve this goal can be through virtual reality (VR) and augmented reality (AR), which have proven their efficacy [Rizzo and Kim, 2005]. These technologies allow the manipulation and coexistence of virtual content within the real environment [Slater, 2009]. Thus, being able to create immersive and plausible experiences to induce the targeted emotions, allow the opportunity to collect contextualised physiological data.

The aim of this work is to propose a model capable of producing contextualised stimuli, collect physiological and external responses, identify and classify emotional patterns, and ultimately, regulate the emotional state by closing the loop.

2. PROPOSED APPROACH

The object of the proposed model is to detect emotional cues from human reactions, integrate emotional responses along time and finally produce a prediction of the transient emotional state. Our approach is mainly composed of four blocks: stimuli generator, patient responses data acquisition, classification, and therapist visualisation/control. The stimuli generator is responsible to provide different sensorial stimuli (e.g. visual, auditory) which will trigger different activations and responses in the patient. The physiological measures and electrophysiological information in real time from the central nervous system (CNS) or peripheral nervous system (PNS) are collected and processed. More specifically, the multimodal physiological signals, e.g., electromyogram (EMG), electrocardiogram (ECG), electroencephalography (EEG), and electrodermal activity (EDA), facial expressions, body parts acceleration, and posture patterns, as well as other features extracted from these acquired signals are fused and used for the patient's emotional state classification. For classification, the use of machine-learning-based methodologies are promising to reveal the latent patterns of certain emotional states hidden in the physiological signals. In particular, deep classifiers are able to abstract the intermediate representations of physiological features in multiple modalities via hierarchical and temporal architectures. The neural network developed for this system includes a single LSTM cell followed by Batch Normalization [Ioffe and Szegedy, 2015.] and a fully connected layer for classification. The dataset used to train it was DEAP [Koelstra et al., 2012], which contains 48 different physiological signals and face video recordings from 32 participants. The classified emotional state provided is represented using the previously mentioned arousal-valence-dominance three-dimensional space. This representation allows the discrimination of multiple discrete emotional states, e.g., neutral, joy, peaceful, fear and angry, that can be defined with different combinations of arousal, valence and dominance levels. The result is presented to the therapist, who can manipulate the stimuli generator system.

2.1 A Closed Loop Model

Typically, exposure-based therapies are delivered in sessions where the therapist brings in disturbing elements paying attention and interacting with the patient. Eventually upon the report or observation of excessive discomfort, escape reactions or other signs those elements may be reduced in number, put away, or removed completely to enable the return to a stable emotional state before starting over, possibly taking a more cautious approach by reducing the intensity of the exposure session. Although being recognised as an efficient method, given that it can be difficult to bring in the phobic elements, or to accompany the patients when the trouble is related with entering specific spaces, like open or crowded spaces, stores, planes, or drive a car along a highway, due to the amount of time that this requires, alternative solutions would be greatly appreciated. It is exactly in this context that VR and AR may come to help, in particular if a setup can be used to create the intended exposure following the parameters established by the therapist.

There are however some drawbacks in the use of VR for this purpose and the first is related with the headset itself, as it hides the eyes and with them most of the expressions of the patient during the exposure session. This may hinder the analysis of the reactions of the patient by the psychologist. As a replacement solution there is the possibility of analysing automatically a set of easy to acquire signals, such as those related with head accelerations or movements and may be related to escape reactions. In addition, and as mentioned above, there is a link between emotions and autonomic reactions such as HR increase, sweating, muscle tension, etc. This calls in a natural way to the application of a machine learning based approach for analysis of activation-related signals. As a result, it is relatively easy to create a dashboard where the psychologist may observe some of the signals which may provide direct information, such as the heart rate, but in particular the output of the analysis performed by the classifier about the recently received signals.

With these ingredients we may thing about creating an automatic system that controls a game-like environment where the display of activating elements is controlled by a set of parameters defined by the therapist and by the emotional response analysis produced by our classifier. This brings in the structure of a classical control loop as the one presented in Figure 1. In this case the system is composed by one principal loop that includes the emotional state recognition module that is used for the normal function above described, but also a smaller loop whose purpose is to serve as a safety switch of rapid actuation, in the case that the patient is overreacting.

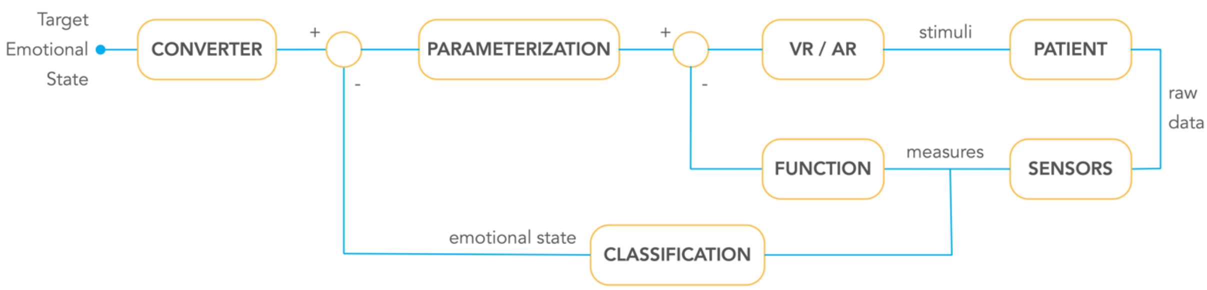


Figure 1. *Emotional regulation model.*

3. SYSTEM ARCHITECTURE

The proposed system, presented in Figure 2, is composed of three main components: a computing unit, a set of sensors and a visualisation module. All the sensors are connected to the computer wirelessly. We are using BITalino, a low-cost device and open source hardware to collect electrocardiography (ECG), electrodermal activity (EDA) and skin temperature (ST) raw signals. For electroencephalography (EEG) power spectrum assessment the device used is the NeuroSky MindWave headset which provides alpha waves and beta waves, as well as eye blinks. In order to track the patient’s posture and facial features we are using an RGB-D camera pointing towards the patient. As presented before, there are three types of visualisation methods: augmented reality, virtual reality and guided imagery. The reasoning behind it is the fact that exposure therapies have different constraints that can be overcome by changing the visualisation method. Two examples can be the fear of flight which can benefit from a virtual reality setup or the fear of contamination where augmented reality could have greater impact by having the phobic element coexisting with the patient's real hand.

To better illustrate the proposed system, we conduct an experiment that features an arachnophobia exposure therapy where the number, size, and position of the virtual spiders change according to the patient reactions/emotional state. The experiment can be run following the next. First, the therapist selects the visualisation method (i.e., how the patient will visualise the contents) which can be through augmented reality, virtual reality or guided imagery instructions. This will flag the scene generator to adapt its contents to the proper method. Next, the therapist must select the desired emotional state (i.e., the goal of the therapy) that in this case can be reducing fear of spiders. Finally, the therapist must select all the sensors that the patient is wearing, as well as if it is possible, to use the camera to collect the patient facial information (e.g., in the case of virtual reality the face is occluded by the headset). After this configuration process, the system is ready to run the model as described in the previous section. Preliminary results show positive feedback from general population participants, which is a reinforcing aspect to continue research on the proposed approach.

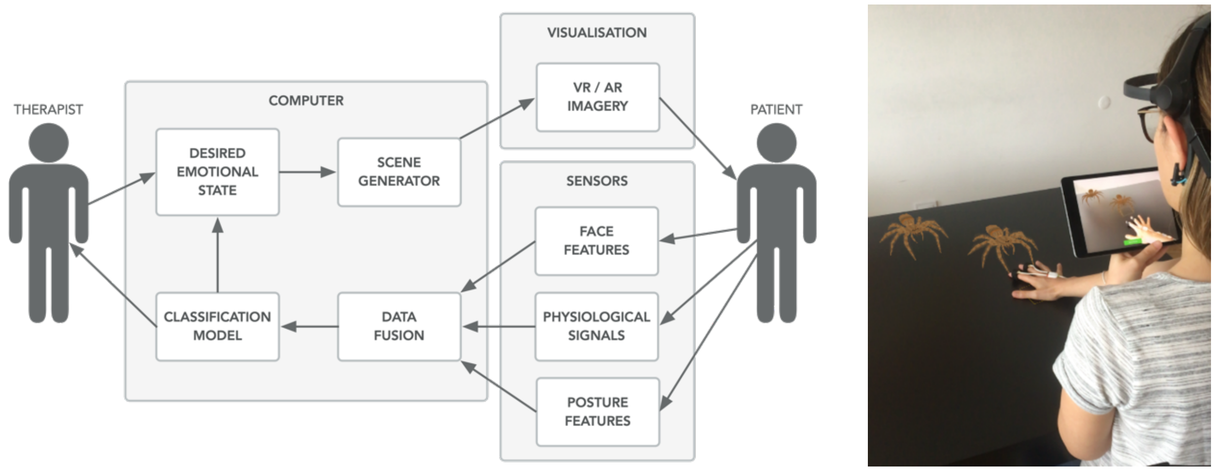


Figure 2. *Proposed System and Apparatus.*

4. CONCLUSION

Our proposed model integrates the ability to induce contextualised stimuli, collect physiological and external responses, identify and classify emotional patterns, and therefore may be a promising tool to assist the process of emotional regulation. As future work, we intend to create our own dataset from different situations and modalities, i.e., collect physiological and visual data triggered using the three distinct visualisation methods presented (virtual reality, augmented reality and guided imagery). For each visualisation method, we will develop similar situations to activate specific emotional states and ask the participants to self-report their subjective emotional state. This will allow a more contextualised training and validation of the proposed model by clinical experts in the psychology field.

5. REFERENCES

Gross, J.J., 1999. Emotion regulation: Past, present, future. Cognition & emotion, 13(5), pp.551-573.

Ioffe, S. and Szegedy, C., 2015. Batch normalization: Accelerating deep network training by reducing internal covariate shift. arXiv preprint arXiv:1502.03167.

Koelstra, S., Muhl, C., Soleymani, M., Lee, J.S., Yazdani, A., Ebrahimi, T., Pun, T., Nijholt, A. and Patras, I., 2012. Deap: A database for emotion analysis; using physiological signals. *IEEE transactions on affective computing*, *3*(1), pp.18-31.

Mauss, I.B., Levenson, R.W., McCarter, L., Wilhelm, F.H. and Gross, J.J., 2005. The tie that binds? Coherence among emotion experience, behavior, and physiology. Emotion, 5(2), p.175. Vancouver

Porges, S.W., 2011. The polyvagal theory: neurophysiological foundations of emotions, attachment, communication, and self-regulation (Norton Series on Interpersonal Neurobiology). WW Norton & Company.

Rizzo, A.S. and Kim, G.J., 2005. A SWOT analysis of the field of virtual reality rehabilitation and therapy. *Presence: Teleoperators & Virtual Environments*, *14*(2), pp.119-146.

Slater, M., 2009. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1535), pp.3549-3557.

Virtual Reality-based Visual Training for Vestibular Rehabilitation

Bruno Ferreira[1,2], Emanuel Pereira[1,3], Paulo Menezes[1,4]

[1]University of Coimbra, Institute of Systems and Robotics,
Dept. of Electrical and Computer Engineering, Coimbra, PORTUGAL

[2]*bruno.ferreira*@isr.uc.pt, [3]*emanuel.pereira*@isr.uc.pt, [4]*PauloMenezes@isr.uc.pt*

ABSTRACT

Vestibular rehabilitation therapy helps individuals deal with many vestibular-related disorders, such as vertigo, visual disturbances, gaze instability, or even nausea. It consists of an exercise-oriented program that is carefully outlined by specialty-trained vestibular physical therapists and should be followed rigorously to ensure natural vestibular compensation and substitution mechanisms. With the successful proliferation of games among all ages, one can think about turning these exercises more pleasing and motivating for patients while focusing on the game, instead of the task they are performing. In opposition to the current trendy research for patients' balance training, we have driven our attention to the visual and gaze related issues. Therefore, we propose a virtual reality-based therapeutic tool that encourages patients to perform the recommended exercises for their recovery plan while simultaneously stimulating their vestibular system through both visual and auditory modalities. Moreover, explores game principles to make the user perform a suggested set of both head and ocular movements, which are translated as a way of interaction with the developed serious games. Similar to the current approaches for gamifying activities, the user's progress can be naturally encoded by a scoring system that may be stored and made accessible to the doctor or therapist for later evaluation. A preliminary evaluation was carried out with expert appraisal, which provided crucial insights for guiding the following steps on the work and future conduction of a pilot study.

1. INTRODUCTION

Spatial orientation, coordinating motion with balance, and maintaining the upright posture are some of the examples that are supervised by visual and proprioceptive senses, but also by our vestibular system [Agrawal, 2013]. The vestibular system's main components are located in the inner part of the ear, consisting of a labyrinth of semi-circular canals and otolith end organs that are continuous with cochlea [Khan, 2013]. The semi-circular canals are essentially three ring-shaped structures filled with endolymph while being situated in each plane that our head can rotate. Therefore, when individuals rotate their heads along a specific plane, it causes this liquid to shift within that specific semi-circular canal, allowing our brain to perceive the rotation performed. On the other hand, the otolith end organs provide information concerning gravitational forces and horizontal/vertical movements in space.

Evidence shows that people who had suffered from diseases or traumatic incidents in these areas are often known for experiencing vestibular-related disorders, such as vertigo, dizziness, gaze instability or balance issues [Burzynski, 2017]. When focusing on the existing visual problems, peripheral vestibular lesions cause a deficient vestibular-ocular reflex (VOR), which leads to the inability to fixate the desired visual targets during head movements. For instance, normal visual processing demands that the observed visual targets should be fixated on the fovea. The process of foveation or gaze stabilization during head motion is achieved by voluntary saccadic eye movements and reflexive controls, such as the VOR and optokinetic reflex, regardless of the execution velocity [Barnes, 2008]. Under normal conditions, both the VOR and optokinetic reflex can accurately elicit compensatory eye movements to match the performed head motion. Given that it can significantly tackle individuals' quality of life by imposing changes in different aspects of their daily living, people suffering from vestibular disorders are commonly encouraged to undergo Vestibular Rehabilitation Therapy (VRT) programs.

VRT is commonly based on an exercise-oriented plan carefully designed to alleviate the previously mentioned problems while stimulating compensation mechanisms to retrieve back some functionalities. For instance, despite having lost certain abilities, the brain learns to use other senses to replace the lacking vestibular system [Chen, 2019]. Moreover, this program typically comprises three different modalities that are promptly advised for patients depending on their disabilities, such as habituation, gaze stabilization, and balance training.

In contrast to other past works that were solely focused on balance training [Meldrum, 2015], this proposal aims to address the visual training by employing playful Virtual Reality (VR) games that follow the same conventional therapeutic principles. Therefore, a low-cost mobile VR application with different mini-games that focus on different therapeutic purposes is presented to complement the patient's therapy sessions.

2. DEVELOPING SERIOUS GAMES FOR VESTIBULAR REHABILITATION

Literature states that gaze instability is due to the decreased gain of the vestibular response to head movements [Han, 2011]. The best stimuli for recovering it into normal conditions is by performing a visual process called retinal slip. Retinal slip is defined as the image motion on the retina during head motion, and can be induced by horizontal/vertical head movements while maintaining visual fixation on a target. Therefore, patients are frequently encouraged to perform exercises that reinforce these head movements, given that repeated periods of retinal slip are known for inducing vestibular adaptation [Lotfi, 2016]. Other approaches to tackle this diminished component of the VOR include performing the same head movements while blinking throughout the motion. This process leads patients to perform corrective saccades that properly generate the necessary drift to match the head motion, or in other cases, to rectify the excessive drift that may occur in the opposite direction.

According to Herdman et al. in [Herdman, 2007], the recommended gaze stability training should be performed four to five times daily for a total of twenty to forty minutes/day, in addition to twenty minutes of balance and gait exercises. By carefully following these instructions over time, patients are able to improve gaze and postural stability, but also to reduce vertigo sensation. As a matter of fact, the main objective is to improve their quality of life, by leading them to recover some of the lost abilities to perform simple to complex daily living activities. However, individuals with vestibular-related disorders are frequently diagnosed with depression and anxiety, as a result of the amount of time that is needed for their recovery. Together with the fact that the recommended tasks are boring to perform, they often show a lack of commitment and interest to the proposed recovery plan by their therapists. Therefore, one may think of gamifying the previously mentioned exercises by providing an alternative that seeks to follow the same principles, but intends to increase the patient enthusiasm.

VR is a path worth exploring, given its freedom of design to produce interactive environments and its more established usefulness in therapies. It provides safe and customizable training that can be tailored to each patient's abilities/difficulties and comprehend the different variations that the exercises should comprise [Ferreira, 2020]. For instance, varying the amplitude of the previously mentioned retinal slip, or inducing a wide range of required frequencies of head movements to fulfill the game's purpose. Nevertheless, a study carried out by Bergeron et al. in [Bergeron, 2015] suggested a relationship between the duration of the VR sessions and the magnitude of its therapeutic effects, where results suggest that 150 minutes as a minimum accumulated time of exposure leads to positive and quantifiable outcomes for the patient.

The challenge remains on how to ensure that patients are performing the supposed head and ocular movements. One may think about using eye-trackers to monitor the player's gaze throughout the game, but this comes with additional costs, which turns this idea not suitable for home deployment. Therefore, other alternatives can be explored to evaluate if patients are performing those movements, such as developing scenarios with game elements that require constant interaction (e.g., fixating them for long periods) to increase the game's score. Besides, it can be combined with the user's head pose information obtained from the smartphone's gyroscope, and thus a low-cost solution can be developed for home use.

3. IMPLEMENTATION

From the above, the proposed work relies on the development of a low-cost system that consists of two immersive VR-based mini-games for the most common mobile platforms[1]. The games were developed on the

[1] Demo: http://orion.isr.uc.pt/demovideos/VRTgames.mp4

Unity Engine following the previously mentioned requirements, and they can be played using a regular smartphone and a cheap headset.

The first game is called "LightWorks" and its main purpose is to stimulate horizontal ocular and head movements while maintaining fixation on a visual target. Players are part of the quality control of a light bulbs factory, where they must observe a certain number of lamps that pass in front of them on a conveyor belt, as illustrated in Figure 1. They must fixate the lamps during their whole trajectory while pressing a button that powers the conveyor belt. When it reaches the final destination (the left or right extremity of the conveyor belt), a poll asks either the number of times it has lit or the emitted sequence of colors. The game implementation can have different variations, such as the frequency of appearance of lamps, speed of movement, or the trajectories made to stimulate player's attention.

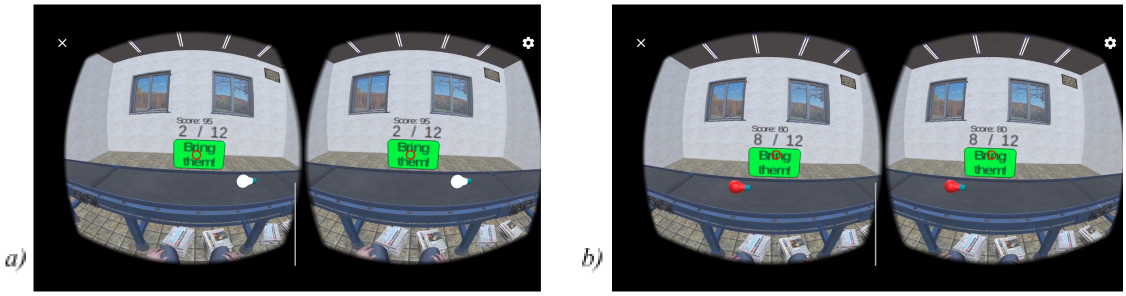


Figure 1. *Gameplay of "LightWorks": a) Lamp has lit; b) Lamp is displaying a sequence of colors.*

The second proposal is called "Labyrinth" where the main objective is to guide the player himself through a mined path until the end of the circuit. This game tries to stimulate both vertical and horizontal movements and lead the user to explore the whole visual field. As the mines are hidden, several instructions appear in the middle of the screen over time. Without losing them from view, they must turn their head accordingly to change the move direction and follow a safe road while either increasing or decreasing their score (e.g., when stepping a bomb). The game has three rounds of difficulty to ease the player's learning curve, but also to enable patients at different stages of recovery to play. Moreover, the game can be adjusted to demand quicker head movements, or to insist more on the affected side on earlier stages.

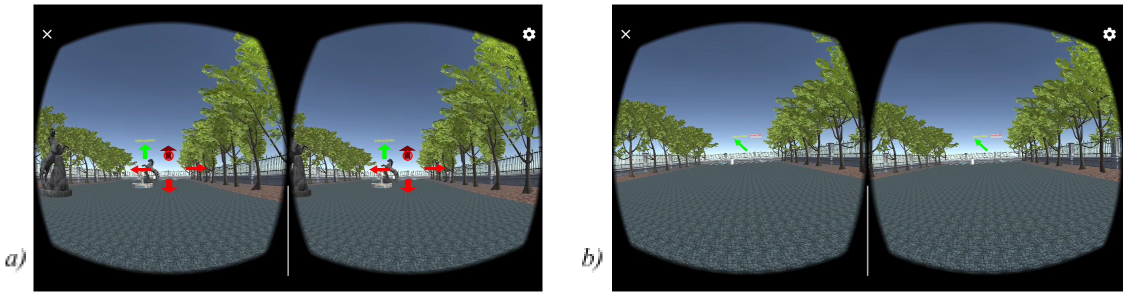


Figure 2. *Gameplay of "Labyrinth": a) Intermediate level: instructions and navigation arrows are shown; b) Advanced level: only the instructions are shown and head controls navigation.*

4. PRELIMINARY EVALUATION

A preliminary evaluation was carried under the supervision of an expert to assess the validity and usability of both created games. The feedback received was positive and validated the previously mentioned requirements, specifically for the second game, as it demands quicker and more complex head movements while maintaining the fixation on a visual target. However, it was suggested that these types of games should focus more on the affected side, while continuously varying the game elements to demand faster/slower ocular and head motions. Such behavior allows patients with acute impairments on their vestibular system to regain or compensate the lost abilities within an expected shorter time. Aside from the games' validated purposes, the specialist referred that patients are indeed typically depressed and tend not to perform the recommended exercises between sessions at home, which has a significant impact on their recovery. Therefore, such a mobile VR application was considered to be interesting, given that it can certainly be used in the clinical space. Still, most importantly, it enables patients to perform their therapy at home.

5. CONCLUSION

This paper presented the development of games that seek to support the conventional procedures of the vestibular rehabilitation, specifically for the gaze training. Under this scope, the different requirements for promoting visual training and how immersive systems can be used to address patients' commitment issues were explored. Two games under a low-cost mobile VR application were presented, and their therapeutic purposes discussed. A preliminary evaluation of these games was performed under the supervision of an expert, confirming the expected interest and validity in both clinical and home scenarios. Therefore, future work on the topic encompasses the development of different games that exploit other recommended exercises and the conduction of a pilot study in a local clinic to evaluate its usability in the recovery of patients with vestibular-related impairments.

Acknowledgments: We would like to sincerely thank Dr. Ana Margarida Amorim of Centro Hospitalar Universitário de Coimbra (CHUC) for all the significant suggestions and enlightenment about the procedures involved in vestibular rehabilitation therapies that were integrated in the design of the presented games.

6. REFERENCES

Agrawal, Y., Ward, B. K., & Minor, L. B. (2013). Vestibular dysfunction: prevalence, impact and need for targeted treatment. Journal of vestibular research : equilibrium & orientation, 23(3), 113–117.

Bergeron, M., Lortie, C. L., & Guitton, M. J. (2015). Use of virtual reality tools for vestibular disorders rehabilitation: a comprehensive analysis. *Advances in medicine*, *2015*

Burzynski, J., Sulway, S., & Rutka, J. A. (2017). Vestibular rehabilitation: review of indications, treatments, advances, and limitations. Current Otorhinolaryngology Reports, 5(3), 160-166.

Barnes, G. R. (2008). Cognitive processes involved in smooth pursuit eye movements. *Brain and cognition*, *68*(3), 309-326.

Chen, S., & Wilkinson, E. (2019). Mechanism of Compensation After Unilateral Loss. In *Diagnosis and Treatment of Vestibular Disorders* (pp. 17-24). Springer, Cham.

Ferreira, B., & Menezes, P. (2020). Gamifying Motor Rehabilitation Therapies: Challenges and Opportunities of Immersive Technologies. *Information*, *11*(2), 88.

Han, B. I., Song, H. S., & Kim, J. S. (2011). Vestibular rehabilitation therapy: review of indications, mechanisms, and key exercises. *Journal of Clinical Neurology*, *7*(4), 184-196.

Herdman, S. J., Hall, C. D., Schubert, M. C., Das, V. E., & Tusa, R. J. (2007). Recovery of dynamic visual acuity in bilateral vestibular hypofunction. *Archives of otolaryngology--head & neck surgery*, *133*(4), 383–389.

Khan, S., & Chang, R. (2013). Anatomy of the vestibular system: a review. *NeuroRehabilitation*, *32*(3), 437-443.

Lotfi, Y., Rezazadeh, N., Moossavi, A., Haghgoo, H. A., Moghadam, S. F., Pishyareh, E., ... & Khodabandelou, Y. (2016). Introduction of pediatric balance therapy in children with vestibular dysfunction: Review of indications, mechanisms, and key Exercises. *Iranian Rehabilitation Journal*, *14*(1), 5-14.

Meldrum, D., Herdman, S., Vance, R., Murray, D., Malone, K., Duffy, D., ... & McConn-Walsh, R. (2015). Effectiveness of conventional versus virtual reality–based balance exercises in vestibular rehabilitation for unilateral peripheral vestibular loss: results of a randomized controlled trial. *Archives of physical medicine and rehabilitation*, *96*(7), 1319-1328.

Virtual museum to promote accessibility to art and cultural heritage: quantitative study on user experience within a virtual reality task

F C Luz[1], J Oliveira[2], V Flores

[1,2]Hei-Lab, [3]Cicant, University Lusófona,
Lisbon, PORTUGAL

[1]*filipe.luz@ulusofona.pt*, [2]*jorge.oliveira@ulusofona.pt*, [2]*victormeflores@gmail.com*

[1,2]*www.hei-lab.ulusofona.pt,* [3]*www.cicant.ulusofona.pt*

ABSTRACT

This poster presents an original Virtual Reality (VR) application for culture heritage, a location-based VR room with the digital reproduction of first Carlos Relvas XIX century photographic studio, that was the support for an experience study about how subjects are exposed to a VR Museum. This VR app was designed to be exhibited in the Portuguese National Museum of Contemporary Art (Lisbon), during the" Carlos Relvas (1838-1894) - Rediscovered Views Of Portugal exhibition ", allowing museum visitors to enter a XIX century photographic studio and interact with stereoscopic cards with the possibility to analyse them in detail and see the 3D relief effect of stereoscopic photography. This poster gives an overview of the main features of this app and its relevancy for media archaeology studies, but also, presents the conducted study with 105 participants (73 Woman) of pleasure or negative effects during the Carlos Relvas VR experience.

1. INTRODUCTION

Virtual Reality (VR) acts as a form of hybridization from XIX century technologies such as Holmes and Verascope stereoscopic viewers that were mechanisms for apparent traveling through 3D relief photographic images. This vintage immersion technologies have been pushing further is several past periods with the aim to offer a sense of presence in new media formats. The amazing golden era of stereoscopic photography, which could be framed between 1850 to 1920, had contributed for registering images from around the world that reveal habits of the past, history, culture, and, in a way, offer an ontological revisit to periods of the industrial revolution. This cultural heritage has been digitized and preserved although offers some technical issues to the act of revisiting and study the stereo photographic cards, due to the preservation and safety concerns when dealing with the original contents.

This work was the result of previous cultural heritage studies and stereoscopic research, namely, the Stereo Visual Culture (supported by the FCT Foundation Ref. PTDC/IVC-COM /5223/2012) where the outcomes had contributed for mapping visual culture of stereoscopy in Portugal, to create a European network of researchers, as also the presentation of several stereoscopic photographers exhibitions, conferences, and papers. Since the beginning of this research, one of the main questions was related to the issue of presenting the "wow stereo effect" of the XIX century products in museums as also to worldwide researchers that don't have access to the original images. Using stereoscopic projections, 3D televisions were mandatory for the cultural and historical experience in museum stereo exhibitions, however, the relief effect of a Holmes Viewer is not comparable with an anaglyph or Real3D projections (Peixoto, Luz, Oliveira, 2019). As VR technologies are now much more accessible and user friendly, the research team developed the Carlos Relvas Studio VR to increase the immersion and guided experience in this act of remediation, innovating the way users could digitally interact with stereocards, with the aim to share historical contents (cultural heritage of Portuguese photographer Carlos Relvas) and, as also, engaging the museum visitors into the experience of cultural interaction [Forlizzi, Battarbee, 2004].

2. Carlos Relvas Studio VR

Carlos Relvas Studio VR allows museum visitors to be immersed in the Portuguese photographer's first studio through Head Mounted Displays (Oculus Rift). VR has an important impact for virtual museums (Hurst, et.al, 2016) and recent VR technologies offer more user-friendly immersive spaces, such as Thresholds VR Experience (Mat Collishaw, 2017) or Mona Lisa: Beyond the glass (Emissive, 2019), contributing for social interactions and immersive engaging experiences (Carrozzino, Bergamasco, 2010).

Installed on the National Museum of Contemporary Art (Lisbon), visitors could interact with Carlos Relvas Studio VR in a dedicated room (12m2), seated close to a table to force participants to explore the VR environment seated safely and avoiding distractions by external stimuli (Figure 1). During the maximum of 5 minutes, each user has the opportunity to look around the space, listen to the sounds of the environment while interacting with 9 stereo cards disposed on top of the digital table. Using the Oculus Touch controller, users could interact with the digital stereocards, looking the information on both sides and enabling the 3D relief stereo effect in a similar way of focusing a stereo card on Holmes viewer.

Figure 1. *Carlos Studio VR interaction at MNAC (Lisbon)*

Figure 2. *Digital Model of Carlos Relvas Studio VR*

The interactive scenario (figure 2) was modeled in 3d digital software package (3ds max), programmed in a game engine (unity 3D) to present the users with the natural experience of “being there”, as much as life-like as possible, to simulate the presence in photographer studio. The reliable experience of immersive digital spaces can increase with sound interaction (Poeschl, 2013; Sikstrom, 2015), thus, Carlos Relvas VR provides a surround sound environment that was captured at the actual place of Carlos Relvas Casa Estúdio in Golegã (Portugal).

The feedback from museum curators was the fact that this VR app contributed to a more successful exhibition because it has created a relevant buzz into the visitors. However, this study aims to contribute to understanding the impact of VR exposure to the users, evaluating the interactive experience and sense of joy, thus wants to clarify if this VR app can be a truthful recreation of XIX century stereoscopic “wow effect” without the undesired ocular discomforts from previous anaglyph, 3DTV and Real3D projections of stereo cards (Peixoto, Luz, Oliveira, 2019).

3. METHOD

3.1. Sample recruitment and description

The sample for this study comprised university students that were recruited in classes from Psychology and Videogames courses from University Lusófona in Lisbon, Portugal. Recruitment took place by teachers of curricular units related to visual perception. This experiment was part of a curricular activity in visual perception aiming to provide a demonstration of a virtual museum in stereoscopy. The sample was collected according to convenience sampling method. The study sample comprised 105 university students, most of them were women (n = 73), single in terms of marital status (n = 98) of Portuguese nationality (n = 93). The average age was 21 years-old (SD = 6 years), aged between 18 and 50 years.

3.2. Measures

The measures used for this study comprised of self-reports related to user experience and cybersickness in VR. The evaluation protocol was divided in an initial section of sociodemographic data (gender, age, marital status and nationality) and further section with questions addressing the level of familiarization with VR setups and videogames. The final section of the protocol comprised questions assessing user experience including affective responses during VR exposure as well as cybersickness symptoms. We have used the Self-Assessment Manikin scale to assess affective responses due to VR exposure in terms of pleasure, arousal and dominance (please see Bradley & Lang, 1994 for further information on SAM scales).

3.3. Procedure

This study was approved by the ethics committee of the School of Psychology and Life Sciences of the host institution of this study. After recruitment and agreeing with the informed consent, the participants were exposed to the virtual museum with an Oculus Rift S headset displaying the Carlos Relvas Studio. The equipment used for conducting this study was one laptop gaming MSI equipped with VR Oculus Rift. After VR exposure, the participants filled a brief sociodemographic questionnaire along with self-reports of user experience related affective experience with the Self-Assessment Manikin (SAM).

4. RESULTS

4.1. Familiarization with VR setups

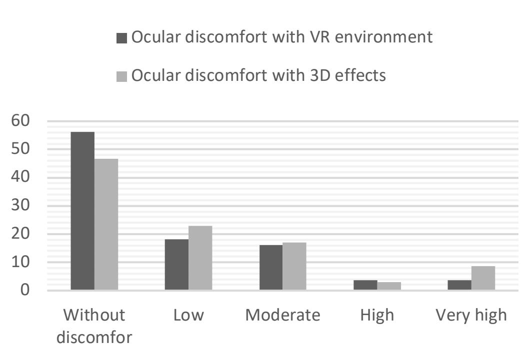
Firstly, we analysed the data concerning the familiarization with VR setups and videogames. This analysis was based on frequency analysis for each variable (questions in the protocol related to 1) level of expertise in using computers, 2) frequency of playing videogames, 3) frequency in using virtual reality systems). These results show that half of participants classified their level of expertise in using computers as intermediate (50%), most consider that play videogames occasionally (60%), and most never tried a VR system before (51%).

4.2. User experience

User experience was analysed according to the SAM scales that allow to assess the affective experience during the VR exposure, in terms of pleasure (in a continuum between negative and positive experience), arousal (between low to high arousal) and dominance (between low to high dominance) related to the VR stimuli/exposure. In a first question we asked participants about the degree of pleasure during the VR exposure. The results show that most participants classified this experience as positive (46%) or very positive (52%). Mean SAM scores were 7,5 for pleasure, 5,9 for arousal and 7 for dominance. SAM scores were also significantly higher than the scale midpoint for the experience for pleasure ($t(104) = 23,314$; $p < 0,001$), arousal ($t(104) = 7,279$; $p < 0,001$) and dominance ($t(103) = 16,335$; $p < 0,001$) as assessed using one sample t test for inference statistics.

We have also explored the relationships between affective experience from SAM scales with sociodemographic data. These results showed significant positive associations through Pearson product-moment correlations between pleasure during the VR experience with age ($r = 0,208$; $p < 0,05$) and between dominance with the level of computer experience ($r = 0,266$; $p < 0,01$), suggesting older participants reported a more positive experience, whereas individuals with higher levels of computer experience reported being more involved in the VR exposure, respectively.

Negative effects due to exposure for ocular effects and discomfort with the hardware (VR headset, controllers, sound) and software (virtual task) were generally low (Figure 3).



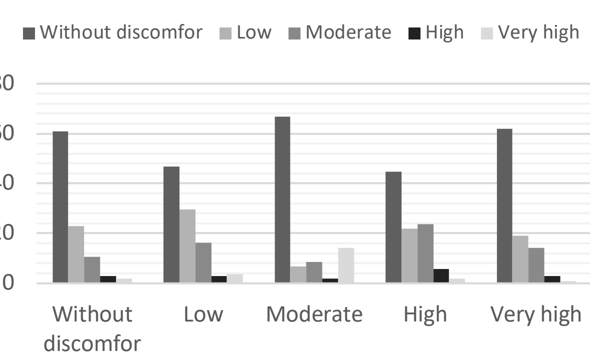


Figure 3. Mean scores for ocular (LEFT) and general discomfort (RIGHT)

4. CONCLUSIONS

The previous experiences of the research team with stereoscopic projections in museums had led this work for a new step into the immersive experience of interacting with digitized XIX century stereo cards, demonstrating the new possibilities for cultural heritage with more reliable when interacting with the digital copies. The self-report data related to emotions felt during VR exposure suggest this as a positive experience as in terms of pleasure, arousal and dominance, the main components of emotional response (Bradley & Lang, 1994). There were also associations with age and computer experience. Both age and computer experience were correlated positively with pleasure and dominance, respectively. Moreover, cybersickness levels seem to be low as both ocular and general discomfort levels were negligible. Overall these data suggest that digitalization of a museum in virtual reality may be a feasible approach to provide art and culture through digital means. Our future work aims to improve the usability of VR applications for museum archives and media studies, enabling new possibilities to interact with art collections, avoiding the use of the original stereo photographs with a correct and reliable relief effect.

Acknowledgements: The authors would like to thank the support from to FCT project UIDP/05380/2020 and the valuable participation from HEI-Lab research unit.

5. REFERENCES

Apostolellis, P., Bowman, D. A., & Chmiel, M. (2018). “Supporting social engagement for young audiences with serious games and virtual environments in museums,” in Museum Experience Design. Springer, pp. 19–43.

Bradley, M., & Lang, P. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. J Behav Ther Exp Psychiatry, 2(1), 49-59.

Carrozzino, M,. Bergamasco, M. (2010). Beyond Virtual Museums: Experiencing Immersive Virtual Reality in Real Museums. J. Cult. Herit., vol. 11, no. 4, pp. 452–458.

Forlizzi, J., Battarbee, K. (2004). Understanding Experience in Interactive Systems. Conf. Des. Interact. Syst., pp. 261–270.

Lee, S., Koo, A., & Jhung, J. (2017). MOSKIT: Motion sickness analysis platform for VR games. 2017 IEEE International Conference on Consumer Electronics (ICCE). doi:10.1109/icce.2017.7889213

Peixoto, R., Luz, F., Oliveira, J. (2019). The Digitalization of Analogue Stereo Photographs and the Creation of the Digital Stereo Archive” in Archiving 2019: Digitization, Preservation and Access. Lisboa. Society for Imaging Science and Technology, USA/Portugal. Pp.171-176. ISSN: 2161-8798

Poeschl, S., Wall, K., & Doering, N. (2013). Integration of spatial sound in immersive virtual environments an experimental study on effects of spatial sound on presence. 2013 IEEE Virtual Reality (VR).

Sikstrom, E., de Gotzen, A., & Serafin, S. (2015). Wings and flying in immersive VR — Controller type, sound effects and experienced ownership and agency. 2015 IEEE Virtual Reality (VR).

Wang, Y., Zhai, G., Chen, S., Min, X., Gao, Z., & Song, X. (2019). Assessment of eye fatigue caused by head-mounted displays using eye-tracking. BioMedical Engineering OnLine, 18(1). doi:10.1186/s12938-019-0731-5

Flies - a serious virtual game for cognitive assessment and rehabilitation

I Fajnerová[1], J Hurych[2], A Plechatá[3], F Vorel[4], J Wild[5]

[1,2,3]National Institute of Mental Health (NIMH),

Topolová 748, Klecany, CZECHIA

[4,5] 3dsense Interactive Technologies

Třebízského 1514/4, 120 00 Praha - Vinohrady, CZECHIA

[1]*iveta.fajnerova@nudz.cz*, [2]*jan.hurych@nudz.cz,* [3]*adela.plechata@nudz.cz,* [4]*filip.vorel@3dsense.cz,* [5]*wildl@3dsense.cz*

[1,2,3]*www.nudz.cz,* [4,5] *http://3dsense.cz/*

ABSTRACT

In this project, we aim to develop and validate a serious game *'Flies'* created in a complex virtual environment that requires participants to find and hit a sitting fly in a virtual kitchen. The behaviour of flies can be manipulated through various parameters to increase the difficulty. The game *Flies* was tested using virtual glasses in two different study protocols to test the construct validity and reliability in groups of healthy volunteers. Study 1 was performed in the form of a single session consisting of several game levels with manipulated parameters of fly's behavior (N = 21, 21-60y). The procedure also included standard measures of focused attention, processing speed and visuospatial scanning, and a questionnaire addressing sense of presence. Study 2 applied repeated assessment in healthy subjects (N = 8, 16-34y) in order to test the reliability of the task. We have monitored the hit reaction times and the hit distance error of successful hits. Preliminary results are presented and discussed in means of validity and reliability of the *Flies* game.

1. INTRODUCTION

Cognitive deficits caused by a cognitive decline in the elderly, neurological or psychiatric disorders often affect various cognitive functions. However, alteration of rudimentary cognitive processes such as attention, psychomotor speed and visuomotor abilities might also affect higher cognitive functions. Hence it is crucial to evaluate these processes and treat their possible deficits. Therefore we strive to create a tool that would allow for sensitive assessment and rehabilitation of visual perception, attentional processing and visuomotor coordination.

Over a period of a year, a VR application *Flies* has been created by NIMH in collaboration with *3dsense* studio responsible for technical development. The application has been tested on healthy volunteers and a small sample of schizophrenia patients and seniors with subjective complaints of cognitive decline or MCI (not reported here). In this paper, we report preliminary results of the late prototype of *Flies* from two quantitative studies. The aim of Study 1 was to evaluate the construct validity (Parsons and Rizzo 2008) through comparison with the standardized methods that are commonly used to measure attention (especially visuospatial scanning) and processing speed. The aim of Study 2 was to explore the reliability of *Flies* using repeated assessment.

2. METHOD

2.1 General description of the serious game 'Flies'

The serious game application was created using game engine Unity®Pro software. The task takes place in a corner of a virtual kitchen environment, we have restricted the active virtual space to limit potential cybersickness and to allow participation of people with restricted movement capabilities. The flies emit typical sounds while flying, although in the current version the sounds do not originate at the location of a fly and thus cannot be used to track it. Flies can occupy one of 8 target circular areas (heliports) located in front of the participant (see Fig.1). The task of the player is always to hit a fly as quickly as possible after it lands (a fly in flight cannot be hit). The task was designed to address focused attention, visuomotor coordination and psychomotor speed. Individual levels (rounds) can be controlled by several parameters: level duration; the total number of flies and number of flies present simultaneously; number of active heliports and their sequence; a pause between flies; the flight speed; whether and when a fly can leave a heliport. Moreover, the way the flies appear can be manipulated - either they appear immediately on a heliport or they fly towards it. Also some aesthetic parameters such as a fly size can be adjusted.

Both studies were conducted with an HTC Vive Pro headset with one controller as a virtual flyswatter. The protocol always starts with a tutorial - participants are acquainted with the environment, the positions of heliports and with the use of a flyswatter, which they are asked to practice by hitting flies sitting at each heliport. The following levels vary in parameters (see Methods, Study 1,2). Detailed data about the position of the headset and the controller as well as positions of flies and participants actions have been recorded. Moreover, the spatial precision (hit distance error = distance from the center of the flyswatter to a fly in a moment of hitting it) and hit reaction time (the time since an appearance of a fly on a heliport and the moment it is killed) has been calculated. Quantitative data analysis was performed in R Studio (RStudio Team, 2019).

Figure 1. ***Visualization of the virtual environment applied in the serious game Flies (first-person view).*** *The game tutorial shows the heliports (left). Heliports are not highlighted during the assessment. Illustration of the visual feedback provided to the participant after a successful hit (right).*

2.2 Study 1- validity

The aim of the first study was to test the construct validity of the serious game *Flies*. Sample of 21 healthy participants (13F/8M) with age ranging from 21 to 60 years (M = 31.05, SD = 8.22) was recruited in the social surroundings of the authors. Prior to *Flies* all participants performed a set of neurocognitive tests aimed to evaluate abilities potentially addressed by the novel VR task: 1) reaction time and focused attention - hit reaction time in Conners' Continuous performance test 3 (CPT; Connors, 2014), Simple response time (SRT) in PEBL 2.0 (Mueller, Piper, 2014); 2) psychomotor speed and executive functioning - the Trail making test (TMT; Preiss, Preiss, 2006) A and B (times); and 3) visuospatial scanning - Bell test - total time (Gauthier et al., 1989).

Afterwards. participants underwent the virtual task *Flies* consisting of a tutorial and four levels. Level 1 - 20 flies were immediately appearing only on three preselected heliports, Level 2 was the same except that the flies were 'landing' on the heliports. The order of these two levels was alternating between participants. Levels 3 and 4 were both limited by the duration of 5 minutes and all 8 heliports were opened, in former there was only one fly present at every given moment and a pause between flies was 8 seconds, in the latter there were two flies simultaneously present and the pause was 1 second. Subsequently participants responded to our own questionnaire (including questions about their experience and cybersickness) and Ingroup Presence Questionnaire (IPQ; Schubert, 2003). The averaged **hit reaction time** measured in individual levels of *Flies* was analyzed using correlation analysis (Spearman's rho).

2.3 Study 2 - reliability

Eight healthy volunteers (4F/4M) aged 16-34 years (M = 24.75, SD = 6.58) participated in a short study during a mental health festival organised by NIMH that was opened to the general public. First they performed approx. a 10 minutes long task in *Flies* (updated version) consisting of a tutorial and two levels. In Level A 40 flies flew to the heliports while in Level B they immediately appeared at the heliports although in a different order. Directly afterwards participants filled out our own questionnaire and performed a re-test of the same task in VR omitting the introductory tutorial. During the task two dependent variables were measured: **the hit reaction time** and **hit distance error**. The averages of these were consequently tested by Spearman's rho for correlations between test and retest assessments.

3. RESULTS

3.1 Study 1 - validity

The Spearman's correlation analysis revealed a significant positive association between the **hit reaction time** measure and the performance in the Bell test (total time, when a participant was sure he has found all the bells) and the TMT A task variant, while no correlation was identified between this measure and the reaction times measured using CPT and SRT (see Table 1). IPQ results (scale of 0-6) are as follows: general presence [1 item]: Mean(SD) = 4.67(1.15); spatial presence [5]: 4.8(1.05); involvement [4]: 3,33(1.6); experienced realism [4]: 2.44(0.95). Participants found (on 0-6 scale) the task in *Flies* rather easy in terms of attention 2.5(1.57) and coordination 2.1(1.48) and rather enjoyable 4.86(1.2), no (n=17) or very mild (n=5) cybersickness was reported.

Table 1. *Descriptive statistics and correlations (Spearman's rho) of measured variables (abbr. in Methods)*.

Variable	M	SD	TMT_A	TMT_B	Bell	SRT	CPT	Level1	Level2	Level3
TMT_A	27.07	9.84								
TMT_B	71.89	21.55	0.365							
Bell	130.07	38.41	0.127	0.212						
SRT	280.6	32.04	0.044	0.129	0.168					
CPT	362.8	33.12	**0.456***	0.344	0.095	0.401				
Level1	0.909	0.199	0.321	0.227	0.26	0.128	0.289			
Level2	0.604	0.173	**0.515***	0.022	**0.527***	-0.083	0.236	**0.662****		
Level3	1.176	0.536	**0.439***	0.018	0.248	-0.336	-0.003	0.328	**0.598****	
Level4	0.994	0.239	**0.517***	0.211	0.406	-0.031	0.187	**0.561****	**0.712****	**0.725****

Note: M and SD represent mean and standard deviation in seconds. Levels 1-4 represent averaged hit reaction times in Flies (in seconds); * indicates p < .05. ** indicates p < .01.

3.2 Study 2 - reliability

Concerning the *hit reaction time* we measured significant moderate test-retest correlations: for the Level A, where the flies were landing on heliports it is $r = 0{,}762$ $(p = .038)$ and for the other Level B, where the flies were immediately appearing on the heliports it is $r = 0.810$ $(p = .022)$. Regarding the *hit distance error*, obtained test-retest correlation coefficients differed between levels: for Level A ($r = 1$; $p < .001$) and for Level B ($r = 0.706$; $p = .05006$). Participants found the VR task rather easy in terms of attention M = 2.5(SD = 1.07) and coordination 2.65(1.6) and enjoyable 5.13(0.64), only one participant reported cybersickness although moderate (3), these data were gathered again on 0-6 scales.

4. DISCUSSION & CONCLUSIONS

Presented tentative findings of the two studies indicate the *Flies* task construct validity can be explained in means of visuospatial scanning and possibly visuomotor coordination. However, the hit reaction time findings cannot be directly linked to simple reaction times measured in focused attention tasks such as CPT and SRT. This could be explained by the visuospatial complexity of the *Flies* task. In the future analyses we plan to utilize the so-called 'initiation time' (the time since the fly's landing to the moment a participant initiates the swat movement) as another variable addressing internal processing. However, feasibility of this approach remains to be tested. Moreover, we lacked specific visuomotor task and a comparison with specific groups, where we could expect distinct results in means of psychomotor speed (seniors and patients with mental health issues). Unfortunately, it was not possible to finish the assessments according to the original plans, due to the social distancing required since March 2020. We hope to address these limitations in future studies.

The reliability of *Flies* cannot be confirmed by the presented data acquired from such a small sample. However, the preliminary data seem promising. This indicates that the late *Flies* prototype enables repeatability required for cognitive assessment. However, originally implemented features, intended to increase presence (turned off in this study), could be potentially applied in rehabilitation of neurocognitive deficits in seniors or neuropsychiatric disorders.

Acknowledgements: This study was supported by the Technological Agency of the Czech Republic (TA ČR) project no. TL01000309, and partially by the European Regional Development Fund-Project "PharmaBrain" No. CZ.02.1.01/0.0/0.0/16_025/0007444.

5. REFERENCES

Conners, CK, (2014). *Conners Continuous Performance Test 3rd Edition*. Multi-Health Systems Inc, Toronto.

Gauthier, L, Dehaut, F, and Joanette, Y, (1989). The bells test: a quantitative and qualitative test for visual neglect. *International Journal of Clinical Neuropsychology*. 11, pp. 49–54.

RStudio Team (2019). *RStudio: Integrated Development for R. RStudio*, Inc., Boston, MA URL http://www.rstudio.com/.

Mueller, ST, and Piper, BJ, (2014). The Psychology Experiment Building Language (PEBL) and PEBL Test Battery. *Journal of neuroscience methods*, 222, pp. 250–259.

Parsons, TD, Silva, TM, Pair, J, Rizzo, AA, (2008). Virtual Environment for Assessment of Neurocognitive Functioning: Virtual Reality Cognitive Performance Assessment Test. *Stud Health Technol Inform*; **132**, pp.351-356.

Preiss, M, and Preiss, J, (2006). Test cesty [Trail Making Test]. Psychodiagnostika, Brno.

Schubert, T, (2003), The sense of presence in virtual environments: A three-component scale measuring spatial presence, involvement, and realness. *Zeitschrift für Medienpsychologie*, 15, pp. 69-71.

Visuomotor adaptation in HMD-VR increases cognitive load

J M Juliano[1] and S-L Liew[2]

[1] Neuroscience Graduate Program, [2]Chan Division of Occupational Science and Occupational Therapy, University of Southern California (USC), Los Angeles, CA, USA

[1]*juliaang@usc.edu*, [2]*sliew@usc.edu*

ABSTRACT

Converging evidence finds that learning complex motor tasks in virtual reality using a head-mounted display (HMD-VR) may increase cognitive load and decrease motor performance compared to conventional computer screens (CS). Separately, visuomotor adaptation in HMD-VR has been shown to recruit more explicit, cognitive strategies during adaptation, resulting in a decrease in implicit mechanisms thought to contribute to motor memory formation. In this preliminary analysis, we measured cognitive load during visuomotor adaptation using a dual-task probe and examined the relationship between cognitive load and mechanisms of adaptation. We found cognitive load to be higher in HMD-VR and that increased cognitive load was related to decreased overall implicit adaptation and decreased explicit, cognitive mechanisms during early adaptation. Future analyses will examine how HMD-VR-related increases in cognitive load affect motor memory retention and transfer to the real-world.

1. INTRODUCTION

There is inconclusive evidence of motor transfer between HMD-VR and the real world and the mechanisms underlying motor transfer between HMD-VR and real-world contexts are unclear (Levac et al., 2019). This variability suggests certain factors or experimental conditions may facilitate or hinder HMD-VR transfer. There is evidence that HMD-VR may result in increased cognitive load during complex motor learning which could have negative effects on retention and transfer (Frederiksen et al., 2020). Separately, there is evidence that HMD-VR visuomotor adaptation may recruit more explicit, cognitive mechanisms during adaptation, resulting in a decrease in implicit adaptation (Anglin et al., 2017). The purpose this analysis is to examine whether HMD-VR visuomotor adaptation increases cognitive load and whether cognitive load is related to mechanisms of adaptation.

2. METHODS

Thirty-six participants were included in this analysis (26 female/13 male; aged: M= 26.5, SD=4.9) with eligibility criteria being right-handedness and no neurological impairments. Written informed consent was obtained from all participants and the experimental protocol was approved by the USC Health Sciences Campus Institutional Review Board and performed in accordance with the 1964 Declaration of Helsinki.

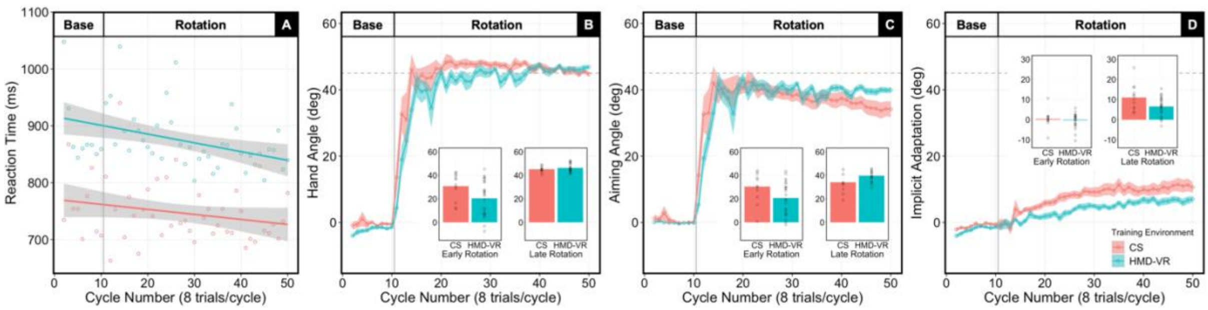


Figure 1. *Means (M) and std. errors (SE) are plotted across cycles.* I*nset bar graphs show group M and SE as well as individuals means during early (fist 4 cycles) and late (last 4 cycles) adaptation.*

We used an established visuomotor adaptation task with a dual-task probe measuring attentional demands as a proxy of cognitive load. Briefly, participants trained in either CS (N=12) or HMD-VR (N=24; Oculus Quest) and completed Baseline (72 trials) and Rotation (320 trials) blocks. During Baseline, participants were instructed to reach towards unperturbed targets flanked by numbers and report the number they were aiming to prior to receiving a visual cue to reach, with the goal of each trial to make a cursor land on the target. During Rotation, a 45° counterclockwise perturbation was introduced and participants needed to counteract the perturbation for the cursor to land on the target. On one pseudorandom trial in each cycle (8 trials/cycle), an auditory cue sounded, and participants were instructed to quickly press a foot pedal before reaching. The reaction time to press the pedal after the auditory cue was used as a measure of cognitive load (CL). Reported aim during adaptation was used as the aiming angle, and the difference between aim and hand angle was measured as implicit adaptation (IA). We used an inverse gaussian GLMM to examine CL across trials and between groups (random-effects being participants) and unpaired t-tests for comparisons between training environments where $p < 0.05$ was considered significant.

3. RESULTS

Cognitive load. The GLMM analysis indicated cycle number ($\beta_1 = -0.83$, SE = 0.32, t = -2.61, p = 0.009) and training environment ($\beta_2 = 167.39$, SE = 38.41, t = 4.35, p < 0.0001) to be significantly related to CL where training in HMD-VR increased attentional demands (Figure 1A). We also found a significant group difference in average CL during the baseline block (t(27.5) = -3.12, p = 0.004) as well as during the rotation block (t(30.4) = -2.96, p = 0.006) where CL was greater in HMD-VR for both blocks. *Baseline.* To examine differences between training environment at the end of baseline, we compared the last cycle of the baseline block and found no significant differences in hand angle (t(34.0) = 1.55, p = 0.130), aiming angle (t(18.8) = 0.48, p = 0.640), nor IA (t(30.0) = 1.11, p = 0.277). *Rotation*. To examine differences between training environments in early and late adaptation, we compared the first four and last four cycles, respectively. In early adaptation, we found significant differences in hand angle (t(27.8) = 2.31, p = 0.028) and aiming angle (t(23.7) = 2.09, p = 0.047) but not in IA (t(18.7) = 0.47, p = 0.642). In late adaptation, we found significant differences in aiming angle (t(14.5) = -2.28, p = 0.038) and IA (t(17.0) = 2.14, p = 0.047) but not in hand angle (t(29.6) = -1.19, p = 0.244). Figures 1B-D show adaptation curves.

In an initial analysis exploring the relationship between cognitive load and mechanisms of adaptation, we found significant relationships between average cognitive load and aiming angle in early adaptation (F(1,34) = 6.85, R^2 = 0.143, p = 0.013) as well as overall IA (F(1,34) = 4.39, R^2 = 0.088, p = 0.044) where increased cognitive load related to decreased early adaptation aiming angle and decreased overall IA.

4. DISCUSSION

The results of this analysis suggest that visuomotor adaptation in HMD-VR increases attentional demands compared to a conventional computer screen. We showed that while adaptation was similar between environments at the end of training, participants training in HMD-VR took longer to adapt and this could potentially be explained by differences in explicit, cognitive mechanisms (aiming angle) in early adaptation. Moreover, aiming angle was greater in HMD-VR and implicit adaptation was greater in CS at the end of adaptation, replicating our previous findings in Anglin et al. 2017. Lastly, we found that increased cognitive load was related to the aiming angle in early adaptation as well as overall implicit adaptation, suggesting the differences in mechanisms between training environments could potentially be explained by an increase in attentional demands. Future analyses will examine whether these results are related to differences in motor memory retention and transfer to the real-world.

5. REFERENCES

Anglin, J. M., Sugiyama, T., & Liew, S.-L. (2017). Visuomotor adaptation in head-mounted virtual reality versus conventional training. *Scientific Reports*, *7*, 45469.

Frederiksen, J. G., Sørensen, S. M. D., Konge, L., Svendsen, M. B. S., Nobel-Jørgensen, M., Bjerrum, F., & Andersen, S. A. W. (2020). Cognitive load and performance in immersive virtual reality versus conventional virtual reality simulation training of laparoscopic surgery: a randomized trial. *Surg. Endoscopy*, *34*(3), 1244-52.

Levac, D. E., Huber, M. E., & Sternad, D. (2019). Learning and transfer of complex motor skills in virtual reality: a perspective review. *Journal of NeuroEngineering and Rehabilitation*, *16*(1), 121.

Ghostly: An EMG controlled serious game

K Kostkova[1], L Omelina[2], E Swinnen[3], M Degelaen[4], B Jansen[5]

[1,2,5] Department of Electronics and Informatics (ETRO),
Vrije Universiteit Brussels, Pleinlaan 2, Brussels, BELGIUM

[1,2,5] imec, Kapeldreef 75,
B-3001 Leuven, BELGIUM

[3,4] Rehabilitation Research Group, Department of Physiotherapy,
Vrije Universiteit Brussel, Laarbeeklaan 103, Brussels, BELGIUM

[3,4] Inkendaal Rehabilitation Hospital,
1602 Vlezenbeek, BELGIUM

[1]kkostkova@etrovub.be, [2]lomelina@etrovub.be, [3]Eva.Swinnen@vub.be, [4]Marc.Degelaen@vub.be,
[5]bjansen@etrovub.be

[1,2,3,4,5] *www.vub.be*, [1,2,5] *www.imec-int.com*, [4]*www.inkendaal.be*

ABSTRACT

One of the key aspects in a long-term physical rehabilitation is the motivation to persist, especially for children with cerebral palsy, who need repetitive exercises daily. We developed an EMG-controlled serious game in collaboration with experts in physiotherapy and rehabilitation sciences. Using non-invasive surface-EMG sensors ensures that the patient is activating specifically targeted muscles while playing the game. The EMG and game data captured during the gameplay are used to create a report, to track not only the game performance, but also the rehabilitation progress. We released the source code of the game under the GPLv3 license, enabling free use and modifications.

1. INTRODUCTION

Cerebral Palsy (CP) is the most prevalent childhood disability, affecting 3 in 1000 children (Prevalence of Cerebral Palsy, n.d.). In a large percentage of children with CP, other development disabilities are co-occurring, e.g. autism, epilepsy, intellectual disabilities, or visual impairment (Data and Statistics for Cerebral Palsy, 2019). This leads to a need of a long term or lifelong physical and/or occupational therapy (Individuals with Disabilities Education Act (IDEA) Services, 2019).

Physical therapy is focused mainly on the engagement of a specific muscle(s) and can improve (or slow the degradation of) muscle function. There are different types of therapeutic programs available for children with CP. Intense, repetitive task therapy is associated with the highest level of effectiveness (Damiano, 2009). Moreover, the physical therapy is not limited to the interaction with a physiotherapist but also includes hours of repetitive exercises performed at home. The challenging nature and repetitiveness of the motion can lead to boredom and low adherence to the training plan.

Motivation of a patient is the key to his adherence and compliance with physical therapy. It was shown that gamification of the physiotherapy and/or use of computer games in strength-training have positive effects on patient's motivation and adherence to the therapy (Bryanton, et al., 2006).

In this paper we present a new EMG controlled serious game targeted for children with CP. We make use of our modular platform OpenFeasyo (Omelina, Kostkova, Bonnechere, Van Sint Jan, & Jansen, 2020) which we extended with several novel modules. We have open sourced the OpenFeasyo platform (www.openfeasyo.org) as we believe that it can be beneficial for the research related to physical rehabilitation, as well as for the daily practice of physiotherapists.

2. RELATED WORK

The use of EMG controlled games and/or EMG assisted tools in rehabilitation is not a new idea. It uses principles from biofeedback in modern exergaming. In their review on biofeedback in rehabilitation, Giggins et al described the principle as using "surface electrodes to detect a change in skeletal muscle activity, which is then fed back to the user usually by a visual or auditory signal." (Giggins, Persson, & Caulfield, 2013). This has shown to be particularly useful to increase activity in a weak or paretic muscle, to decrease muscle tone in spastic muscles or to reduce undesired co-contractions. As such, it finds its application in musculoskeletal and neurological rehabilitation. Whereas Giggins and his colleagues reviewed solutions for a variety of patient populations, the Cochrane review (Woodford & Price) focuses on EMG biofeedback systems for the recovery of motor function after stroke. Both reviews found studies clearly documenting improved patient outcomes. However, also studies not showing any impact are reported. Altogether, further work is needed both on the development of appealing and easy to use systems, as well as on the validation of these approaches.

We identified several, more recent systems related to the system proposed in this paper. Liu et al, developed an upper limb rehabilitation training system for children with CP, combining accelerometers and surface electromyography (Liu, et al., 2017). The system contained 3 games and run on an Android platform. After a long-term intervention training with the system, children with CP improved their game performance and motor control.

Yoo et al., developed an EMG virtual-reality (VR) biofeedback system on neuromotor control in children with CP. They investigated the effectiveness of EMG biofeedback with the use of VR, and provided evidence of added value of VR in enhancing upper limb function of children with CP (Yoo, Lee, Sim, You, & Kim, 2014).

Shushong and Xia used an EMG-driven computer game in the rehabilitation of post-stroke patients. Important rehabilitation goals can be achieved in the first 24-48 hours after stroke. EMG-driven computer games can be used during this early rehabilitation phase, even during first hours after the hospital admission, while the patient is lying in bed. (Shusong & Xia, 2010).

3. SYSTEM DESIGN

To support EMG controllers in the Ghostly game, we extended the open source OpenFeasyo platform with several novel modules. The modular nature of the platform enables integration of any surface EMG sensor as well as addition of any new games. In relation to the Ghostly game, we introduced three modules into the platform:

***The Ghostly game module**, which* contains the game logic, the level designs, and graphic design.

The EMG signal processing module which handles communication with an sEMG sensor, preprocessing, and real-time processing of the EMG signal.

The reporting module is responsible for visualization of the game and EMG data.

3.1. Ghostly Game Design

With consideration of our target audience – children with CP who might also have visual or cognitive impairment - we created a 2D game, with simple graphics, instead of a full immersion system running on VR glasses. Ghostly is a platformer game inspired by the old-school games. The game contains 90 levels split equally into 3 graphical themes (worlds): Earth, Water, and Rock, Figure 1 (a).

The goal in each level is to help the avatar reach the EXIT sign, by controlling his actions – jumping (or swimming) and shooting. Along the path the avatar needs to jump on platforms (swim around obstacles) to collect the coins and to avoid or shoot the enemies of varying strength.

The actions of the avatar are controlled with muscle activity measured by two sEMG sensors (one controlling jumping/swimming, one controlling shooting – the avatar advances automatically in the game). The game can be played with any muscle of the body. The selection of the sensor placement is in the hands of the physiotherapists and can be tailored to the needs of each patient, Figure 1 (b).

(a) (b)

Figure 1: *(a) Ghostly game level (b) Ghostly game controlled with sEMG sensors*

3.2. EMG Signal Processing Design

Communication with each type of sensor is different and is defined by the sensor's communication protocol. We introduced abstraction of the EMG sensors such that different types of sensors can use the same signal processing algorithms. The abstracted EMG module is interfacing the communication between the sensor and the game.

From the sensors we currently support, some enable Bluetooth communication and can be used with the Android version of the Ghostly game. Other sensors require communication via a serial port and can be used with the Windows (desktop) version of Ghostly.

To process the EMG signal and detect the muscle activation, we used the method described by Kamen & Gabriel (Kamen & Gabriel, 2009). The method consists of following steps:

Pre-processing:

1. Calibration of the muscle resting state - the calibration should be performed before each game play. The calibration requires the player to rest the muscles. Baseline mean ($\bar{x}_{baseline}$) and standard deviation ($\sigma_{baseline}$) are computed on calibration data of twice the size of the sampling rate.

Real-time processing:

1. Band-pass filtering – the incoming signal is filtered eliminating the signal which is out of the 5-25 Hz range.
2. Full-wave rectification – using the absolute value of the signal rectifies its negative component.
3. Moving average filtering – averaging the signal over a short window (1/10th of the sampling rate) improves robustness and avoids filter misdetections or very short accidental activations.

$$s(\mathrm{t}) = \frac{1}{n} \sum_{j=t-(n-1)}^{t} x(t) \quad (1)$$

where *s(τ)* is smoothed signal, *n* is the window size, and *x(t)* is the signal (result of previous steps) at a specific time point *t*

4. Threshold detection – declaring a threshold above which the EMG signal is considered as the muscle activation. The threshold is set during the calibration step and the following criterion is applied to determine whether a muscle is activated:

$$act(x) = \begin{cases} 1, \; if x > (x_{baseline} + 3 * \mathrm{s}_{baseline}), \\ 0, \; otherwise \end{cases} \quad (2)$$

where *act(x)* is result of thresholding, *x* is the smoothed EMG signal, result of previous step.

3.3. Emg Game Report Design

The Ghostly game collects data (date, time, game level, score, and EMG signal) during the gameplay. All the information we collect is stored in an open c3d file format (Cramp, 2020) for further post-processing, reporting, and visualization.

Figure 2 shows part of the Ghostly game report visualizing the muscle contraction, in relation to actions in the game (jumping, shooting) and where in the game level the player was at that moment.

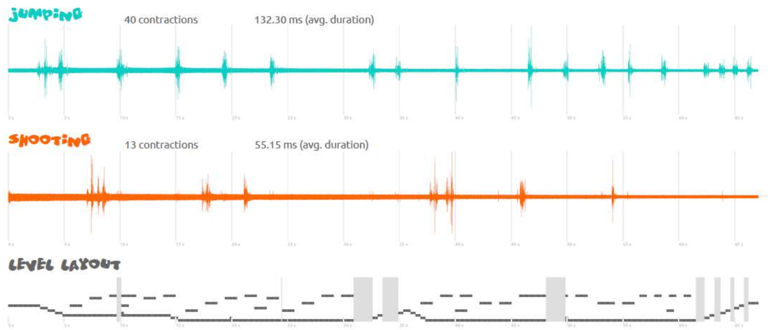


Figure 2: *Ghostly Game Report*

4. VALIDATION

Currently the system – an Android tablet, Ghostly game, and 2 Delsys Trigno Avanti sensors – is available in a rehabilitation center in Brussels. The therapists can use the Ghostly game as a part of their rehabilitation sessions. The use of the system is informal and voluntary. We anticipate the game will be used by rehabilitation scientists and physiotherapists in rehabilitation of children suffering from neuromotor conditions as cerebral palsy.

5. FUTURE WORK

Currently, we are designing an intervention study in collaboration with the Center of Pediatric Neurological Disorder in Brussels. The patient data will enable us to study the changes in the EMG signal, give us the opportunity to study the potential of detecting muscle fatigue and potentially adapt the game to react to it. The interaction with therapists, will provide insight into their needs and will lead to adaptations of the clinical report.

Our system currently supports three sEMG sensors - Shimmer3 EMG Unit (Shimmer3 EMG Unit, n.d.), FlexVolt, FlexShield (Flynn, n.d.), and Delsys Trigno Avanti (Trigno Avanti Sensor, n.d.), but we plan to add support to more sensors, specifically the ones used and preferred by the therapists.

We plan to add more levels and themes to the Ghostly game e.g. ice levels. Ghostly is the first EMG controlled game we developed, and we plan to add other games soon.

6. CONCLUSION

The Ghostly game is part of our modular system which separates the game (its logic and design), from EMG signal processing. This separation enables us to easily add support to new sEMG sensors, as well as to develop new EMG controlled games. Our modular system is available as open source to encourage a collaboration among research community, developers, and therapists.

The Ghostly game we developed is currently in an informal use in one of the rehabilitation centers in Brussels and we are preparing an intervention study with the Center of Pediatric Neurological Disorder in Brussels.

Acknowledgements: Application development was supported by the De Luca Foundation and Delsys, Inc.

7. REFERENCES

Bryanton, C., Bosse, J., Brien, M., Mclean, J., McCormick, A., & Sveistrup, H. (2006). Feasibility, Motivation, and Selective Motor Control: Virtual Reality Compared to Conventional Home Exercise in Children with Cerebral Palsy. *Cyberpsychology & Behavior, 9*(2), 123-128.

Cramp, E. (2020, February 18). *The C3D Standard*. Retrieved from C3D: www.c3d.org

Damiano, D. L. (2009). Rehabilitative therapies in cerebral palsy: the good, the not as good, and the possible. *Journal of child neurology*, 1200–1204. doi:10.1177/0883073809337919

Data and Statistics for Cerebral Palsy. (2019, 4 30). Retrieved from www.cdc.gov: https://www.cdc.gov/ncbddd/cp/data.html

Flynn, B. (n.d.). *Flexvolt Biosensors - Products*. Retrieved from Flexvolt biosensors: https://www.flexvoltbiosensor.com/products/

Giggins, O. M., Persson, U. M., & Caulfield, B. (2013). Biofeedback in rehabilitation. *Journal of neuroengineering and rehabilitation*. doi:10.1186/1743-0003-10-60

Individuals with Disabilities Education Act (IDEA) Services. (2019, 4 30). Retrieved from www.cdc.gov: https://www.cdc.gov/ncbddd/cp/treatment.html

Kamen, G., & Gabriel, D. A. (2009). *Essentials of Electromyography* (First edition ed.). Human Kinetics, Inc.;.

Liu, L., Chen, X., Lu, Z., Cao, S., Wu, D., & Zhang, X. (2017, March). Development of an EMG-ACC-Based Upper Limb Rehabilitation Training System. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 25*(3), 244 - 253. doi:10.1109/TNSRE.2016.2560906

Omelina, L., Kostkova, K., Bonnechere, B., Van Sint Jan, S., & Jansen, B. (2020). OpenFeasyo: Open source serious gaming platform for physical rehabilitation and clinical motion analysis. *Procedings 13th ICDVRAT with ITAG.* Serpa.

Prevalence of Cerebral Palsy. (n.d.). Retrieved from www.cerebralpalsy.org: https://www.cerebralpalsy.org/about-cerebral-palsy/prevalence-and-incidence

Shimmer3 EMG Unit. (n.d.). Retrieved from Shimmer sensing: https://www.shimmersensing.com/products/shimmer3-emg-sensor

Shusong, X., & Xia, Z. (2010). EMG-driven computer game for post-stroke rehabilitation. *2010 IEEE Conference on Robotics, Automation and Mechatronics.* Singapore, Singapore: IEEE. doi:10.1109/RAMECH.2010.5513218

Trigno Avanti Sensor. (n.d.). Retrieved from Delsys: https://www.delsys.com/trigno/research/#trigno-avanti-sensor

Woodford, H., & Price, C. (n.d.). EMG biofeedback for the recovery of motor function after stroke. *Cochrane Database of Systematic Reviews 2007.* Issue 2. doi:10.1002/14651858.CD004585.pub2

Yoo, J. W., Lee, D. R., Sim, Y. J., You, J. H., & Kim, C. J. (2014, September). Effects of innovative virtual reality game and EMG biofeedback on neuromotor control in cerebral palsy. *Bio-medical materials and engineering, 24*(6), 3613-8. doi:10.3233/BME-141188

Simulating Lens Distortion in Virtual Reality

Niklas Stein[1], Katharina Rifai[2], Siegfried Wahl[3], Markus Lappe[4]

[1,4] University of Münster,
Fliednerstr. 21, Münster, Germany

[2,3]Carl Zeiss Vision International GmbH,
Turnstraße 27, Aalen, Germany

[1]*Niklas.Stein@wwu.de*, [2]*Katharina.Rifai@zeiss.com*, [3]*Siegfried.Wahl@zeiss.com*, [4]*mlappe@uni-muenster.de*

ABSTRACT

Modern progressive lenses are widely used to allow distance and near-view within one lens. Novice users experience motion sickness during adaptation and have problems performing everyday tasks when first using progressive lenses. To evaluate the effects of progressive lens distortion in psychophysical experiments these need to be simulated in real-time. We present a method to generate the distortion pattern of a progressive lens in virtual reality that allows testing perceptual distortions and behavioural consequences of exposure to such distortions. A user study showed that the heading angle on the horizontal axis was significantly underestimated through implemented distortion.

1. INTRODUCTION

All people develop presbyopia with age, and increasing amount of the population correct their myopia, hyperopia or astigmatism using spectacles. Ageing populations all over the world lead to more people needing spectacles to correct conjunctions of multiple corrections. A common approach in lens design for this problem is progressive additive lenses (PAL), which have a distance and a near view zone (see Fig. 1).). In PALs both zones are connected through a gradient corridor in which the magnification changes smoothly in contrast to bifocals with a hard border between the far and near zone. This allows having a lens with correction for near sightedness, refractive errors and without perceiving sudden displacements. Since PALs are used in most spectacles for presbyopia, PAL design has evolved dramatically during the last 40 years (Meister & Fisher, 2008). Although lens-design allows individual lenses created through free-form lens surfacing, some wearers experience motion sickness through their spectacles and most need time to adapt to it. Elderly bifocal, trifocal, and PALs wearers have been found to fall significantly more likely than wearers of single-vision lenses (Lord et al., 2002).

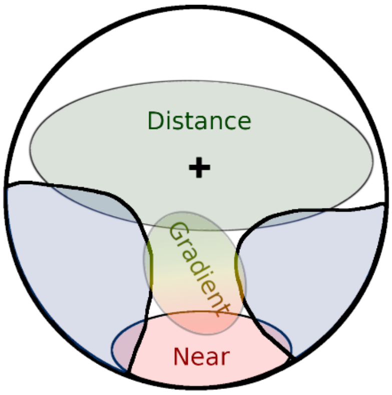


Figure 1. *Schematic of a progressive additive lens and its distortion vectors in the FOV. The gradient corridor between the distance (green) and near view (red) zones leads to unavoidable side-effects in the periphery e.g. skew on both sides of the lens (blue).*

PALs distort the image that reaches the retina differently in different image areas, creating a new mapping between the world and the retinal image. Following Sheedy et al. (2005) this mapping includes astigmatism like distortions in more peripheral areas that follow the physical limitations described in the Minkwitz-theorem (1963) and appear through creating the gradient area. These distortions are a likely source of discomfort and disorientation during locomotion in novel wearers. Faubert & Allard (2004) used a multi-screen system to investigate the effects of a PAL-like distortion on the perception of forward movements. They measured the leaning angle of subjects standing on one foot and found that the distortions generated significant instability. The reason behind this instability may be that distortions produced by a PAL continuously change the optic flow field, i.e. the motion field experienced on the retina during self-motion (Gibson, 1950). Optic flow is used, among other things, for the control of stance (Lee, 1980) and the perception of the direction of self-motion, or heading (Lappe et al., 1999). Habtegiorgis et al. (2017) showed that adaptation effects on PAL-like distortion through display presentation is possible. It thus seems possible to use VR to simulate and investigate the perceptual and behavioural modifications that occur in novel wearers of PALs, since the complete FOV can be distorted in real-time and according to self-motion.

We present a VR method to investigate and compare the possible effects of optical lens designs on visual perception. As a proof of concept we created a user study in which distortion was applied on the field of view (FOV) of a virtual environment in which users were asked to estimate their heading direction.

2. SIMULATION OF PAL DISTORTION IN HMD

All stimuli were presented with the HTC Vive, a Head Mounted Display (HMD) with 2 OLED screens with 1080 x 1200 Px at 90 Hz and a FOV of 110°. A Vive controller was as input device. To track position and orientation we used the lighthouse tracking system. To present the experiment we used Unity3D and the SteamVR asset on a computer with a NVIDIA GeForce RTX 2060 graphics card, an Intel Core i7-8750 CPU with 2.2 GHz, 16 GB of RAM running Microsoft Windows 10.

In an optical lens, light-rays that enter the lens are refracted and thus reach the retina at a different location than in normal viewing. To create a similar effect in a digital image, each pixel position is replaced by a source pixel at a different location in the undistorted image. To simulate a given distortion pattern of a progressive lens in VR, we applied a custom pixel shader on a virtual camera object in Unity3D. By accessing the render pipeline of the graphics processor, shaders can be applied fast on any given environment. Our shader redefined the pixel positions on the x and y axis of both displays in the HMD. For the simulation we used a typical PAL design. The distortion map of a grid of the example lens design was generated through raytracing using a grid consisting of 50 x 50 grid points with an inter grid point distance of 41 mm, seen at a distance of 2 m. To simplify this distortion matrix, we used the curve fitting toolbox of MatLab 2018b to fit two derivable polynomial-functions (see equation 1) to predict the distortion-shift f in x and y-direction for each x and y position ($rmse_x = 0.0021$, $rmse_y = 0.0027$). The fitted 11 parameters of both functions were then passed to the pixel shader. All defined pixels were replaced by source pixels at the calculated x- and y-positions of the undistorted image.

$$f(x,y) = \sum_{i+j=5} (p_{ij} x^i y^j) \qquad i,j,x,y \geq 0 \qquad (1)$$

3. User Study of Heading Perception in Simulated PAL Viewing

3.1 Procedures

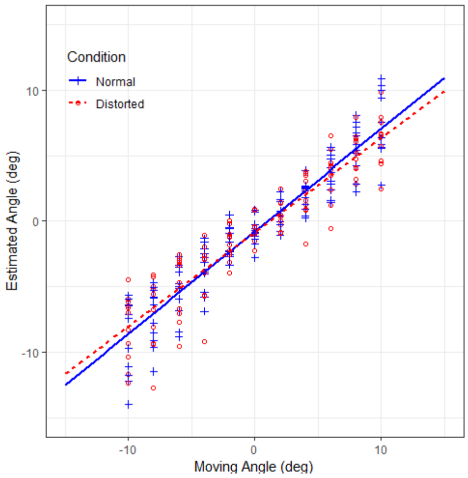


Figure 2. *Left: Underestimation of the heading angle. Through the PAL distortion the heading angle is slightly underestimated. The effect is dependent on the true heading angle. Lines show a linear fit. Right: Distorted (above) and non-distorted FOV at the starting position of the experiment.*

All subjects were asked to sit down. The virtual environment was presented in stereo, although the same distortion was applied to both displays in the HMD. Each subject was asked to adjust the HMD until all edges of a head-fixed aligning-texture were visible and the texture was centred correctly. Then the approximately 15 minutes long experiment started. To estimate distortions of self-motion perception in simulated PAL viewing we conducted an experiment that tested perceived heading direction following established procedures of heading perception research (Warren et al., 1988; Royden et al., 1992; Lappe et al., 1999). In two conditions participants either experienced a distorted or a non-distorted FOV (see Fig. 2), and were instructed to look at a fixation target (diameter of 1 m, positioned 10 m in front of the subject at the height of 0.5 m). The display then simulated forward motion at 2 m/s in one of a set of 11 heading angles (-10, -8, -6, -4, -2, 0, 2, 4 6, 8, 10) for 0.5 seconds. Heading direction and distortion condition varied in a pseudorandom order that was different for each participant. After the motion stopped, participants were asked to indicate their perceived heading direction. A thin vertical red bar was placed on a red circle with a radius of 10 m around the participant. Participants placed the bar in the perceived heading direction by pointing with the controller in their right hand and confirmed by pulling a trigger. To mask the change of distortion between trials the screen greyed out for 0.5 seconds between trials.

Table 1. *Influence of Distortion on Heading:*

	Baseline Model	Comparison Model
(Intercept)	−0.01 (3.86)	−0.01 (3.86)
True Heading	0.75 (0.01)***	0.78 (0.01)***
Distortion	−0.04 (0.10)	−0.04 (0.10)
Rotation y-Axis	−0.06 (0.05)	−0.06 (0.05)
Vision corrected	−0.36 (0.73)	−0.37 (0.73)
Hypothesis	−0.27 (0.72)	−0.26 (0.72)
Age	−0.02 (0.14)	−0.02 (0.14)
Gender	−0.13 (0.71)	−0.13 (0.71)
True Heading*Distortion	-	−0.06 (0.02)***
AIC	13965.27	13959.22
BIC	14048.67	14048.57

Table 1. *Beta weights are shown for all factors (standard errors in brackets). Only the factors True Heading and True Heading* Distortion had a significant influence on the estimated heading direction. Factors with beta weights of 0.00 in both models and were not included (*** $p < 0.001$).*

3.3 Results

shallower than that for the non-distorted view indicating a misperception of heading induced by the distortion. To analyse the data statistically we defined a mixed effect model to predict the perceived heading angles using the control variables *True Heading*, *Gender*, mean *X*-, *Y*- and *Z-Rotation Angle*, *Trial length*, *Trial number* and *Distortion* as fixed effects. The factor *Subject* was added as a random effect. To test if the simulated PAL distortion in interaction with the *True Heading* had an influence on the perceived heading angle, a second model including this interaction was fitted (see Table 1). The second model including the interaction *True Heading*Distortion* was significantly better ($\chi^2 = 14.512$, $p < .001$). The random factor *Subject* explained 13.3 % of the variance in Model 2 ($p < .001$).

4. CONCLUSIONS

We demonstrated that VR can be used to simulate and measure the distortion effects of PALs. The method offers a simple, fast, and efficient opportunity to investigate the distortion created by different lens designs. This is achieved by mimicking and displaying the outgoing image of a PAL, to generate a comparable retinal image. Since the object's distance can be optically translated into size, the distortion map is valid for all distances. In order to show the applicability of the method we conducted a user study comparing self-motion perception with distorted and non-distorted views. As in many studies before (Warren & Hannon, 1988; Royden et al, 1992), subjects were able to estimate their heading direction from the non-distorted visual input. The negative beta coefficient of the interaction of -0.06, suggests that the PAL-distortion led to an underestimation of the heading angle during the experiment. Since the motion vectors of the FOV are asymmetrically changed through the applied distortion a difference in heading estimation seems plausible. In the real wearing of PAL glasses, the observed underestimation may lead to slightly wrong expectations about distance and position of visible objects during self-motion. Thus, distortion may be a factor wearers may need to adapt to. We introduced a method to use cost-efficient hardware to display optical effects of complex progressive lenses and showed in a user study that the PAL-distortion applied through a custom shader led to an underestimation of the heading angle.

Acknowledgements: This work was supported by the German Research Foundation (DFG La 952-4-3) and has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skodowska-Curie grand agreement No. 734227.

5. REFERENCES

Faubert, J., & Allard, R. (2004). Effect of visual distortion on postural balance in a full immersion stereoscopic environment. *Stereoscopic displays and virtual reality systems XI, 5291*, S. 491–501.

Gibson, J. J. (1950). *The perception of the visual world.* Boston: Houghton Mifflin.

Habtegiorgis, S. W., Rifai, K., Lappe, M., & Wahl, S. (2017). Adaptation to skew distortions of natural scenes and retinal specificity of its aftereffects. *Frontiers in Psychology, 8,* 1158. doi:10.3389/fpsyg.2017.01158

Lappe, M., Bremmer, F., & van den Berg, A. V. (1999). Perception of self-motion from visual flow. *Trends Cogn. Sci., 3,* 329-336.

Lee, D. N. (1980). The optic flow field: The foundation of vision. *Phil. Trans. R. Soc. Lond. B, B 290,* 169-179.

Lord, S. R., Dayhew, J., Sc, B. A., & Howland, A. (2002). Multifocal glasses impair edge-contrast sensitivity and depth perception and increase the risk of falls in older people. *Journal of the American Geriatrics Society, 50,* 1760-1766. doi:10.1046/j.1532-5415.2002.50502.x

Meister, D. J., & Fisher, S. W. (2008). Progress in the spectacle correction of presbyopia. Part 1: Design and development of progressive lenses. *Clinical and experimental optometry, 91,* 240–250.

Minkwitz, G. (1963). On the surface astigmatism of a fixed symmetrical aspheric surface. *Optica acta, 10,* 223–227.

Royden, C. S., Banks, M. S., & Crowell, J. A. (1992). The perception of heading during eye movements. *Nature, 360,* 583.

Sheedy, J. E., Campbell, C., King-Smith, E., & Hayes, J. R. (2005). Progressive powered lenses: the minkwitz theorem. *Optometry and Vision Science, 82.*

Warren, W. H., & Hannon, D. J. (1988). Direction of self-motion is perceived from optical flow. *Nature, 336,* 162-163.

Warren, W. H., Morris, M. W., & Kalish, M. (1988). Perception of translational heading from optical flow. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 646.

Developing a 360° video-based Virtual Reality: an explorative and a user experience studies to generate a sexual harassment scenario

Sara Ventura[1], Georgina Cardenas[2], Giuseppe Riva[3], Rosa Baños[4]

[1,4]Department of Personality, Evaluation and Psychological Treatments, University of Valencia
Valencia, SPAIN

[2]Department of Psychology, Universidad Nacional Autónoma de México,
Mexico City, MEXICO

[3]Department of Psychology, Catholic University of Sacred Heart,
Milan, ITALY

[1]*sara.ventura@uv.es*, [2]*cardenas.georgina@gmail.com*, [3]*giuseppe.riva@unicatt.it,* [4]*rosa.banos@uv.es*

ABSTRACT

The 360° camera is a practical and low-cost system that generate 360° content-based Virtual Reality (VR), inducing high sense of presence. The aim of the current work is to explain a useful method to generate a 360° video-based VR for Sexual Harassment (SH) scenario. First, two focus group with women were led to collect information about the SH events in Mexico City. Second, the user experience test was carried to evaluate the quality of the content. The current study is a part of a pilot study that investigates the feasibility of 360° video to study empathy (and related variables) in men in SH scenario.

1. INTRODUCTION

User Centered Design (UCD) is based on the active involvement of the potential user with the aim to improve the usability of the product or the service itself (Mao et al., 2005). The forward step of the UCD is the User Experience (UX), defined as a person's perception and responses that result from the use and/or anticipated use of a product, system, or service (Hassenzahl and Tractinsky, 2006). Specifically, the UX includes individual preferences, and psychological and behaviors responses that happen before, during, and after the interaction with the product, and/or the system (Kolski et al., 2011). Considering the case of Virtual Reality (VR), the environments are often poorly evaluated with users, and the VR content is often created without the voice of the target to who the content is addressed (Triberti et al., 2018).The current study is based on a develop of a 360° video-based VR in a sexual harassment (SH) scenario following the UCD and UX procedures. The study was approved by the Ethics Committee of the Universidad Nacional Autónoma de Mexico (UNAM) with the code EP/PMDPSIC/0151/19.

2. METHOD

2.1 Study 1: Focus Group

The aim of the study was to collect information from women to record the 360° immersive video that reproduces different harassment scenarios.

2.1.1 Participants

Sixteen women participated to the study (M_{age} = 28 years old; SD = 7.37) that matched the inclusion criteria if being an older woman ≥ 18 and do not have been victim of sexual abuse. Consent was obtained from all participants in accordance with the Declaration of Helsinki.

2.1.2 Procedure

The group were led at UNAM and following a structure previously developed by the main researcher (open-ended questions about the typical SH behaviour). Both groups were conducted in Spanish language and last approximately one hour and half.

2.1.3 Results

Theme 1: the women feelings. (a) SH as normalized behaviour, (b) negative feeling, (c) fear, (d) bother, (e) under threat. Theme 2: the environments. (a) public places (public transports, university, street), (b) private place (at home, at work).

2.2 Study 2: User Experience

The goal was to analyse the experience of the user during the exposition of the 360° video, previously recorded.

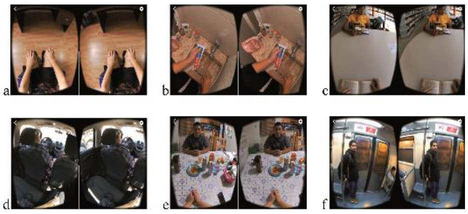
2.2.1 Participants

Ten participants took part at this step: 3 women and 7 men (M_{age} = 25.70, SD = 5.56).

2.2.2 360° Scenarios

The 360° video were recorded with the LG360-105 camera. The camera was hold by the female performer on her head to generate the first-person perspective. We recorded several harass scenarios; then all the videos were edited by the Premiere Adobe program to generate a unique immersive 360° video (Fig. 1).

Figure 1. Screenshots of the sexual harassment scenarios in the 360° video VR experience.



Note. (a) = embodiment induction; (b) = daily activities; (c) = library harassment; (d) = taxi harassment; (e) = spouse harassment; (f) = subway harassment.

2.2.3 Measures

Simulator Sickness Questionnaire: this is a 16-item questionnaire that measures the level of discomfort perceived during the experiment; Motion Sickness Questionnaire: this is a 16-item questionnaire that measures the level of discomfort perceived during exposition due to the 360° environments movements; and Open questions: 8 user experience questions

2.2.4 Results

A one-sample t-test indicated that simulator sickness scores were significantly lower than the chance level of 2 for both factor: Nausea (M = 1.31, SD = .250), t(9) = -8.71, $p < .001$ and Oculomotor (M = 1.43, SD = .398), t(9) = -4.54, $p < .001$. However, the results for the motion sickness scores were significantly lower than the chance level of 2 for the factors Gastrointestinal (M = 1.37, SD = .358), t(9) = -5.51, $p < .001$; Peripheral (M = 1.43, SD = .487), t(9) = -3.74, p = .005 and Tolerance-Related (M = 1.20, SD = .230), t(9) = -11.01, $p < .001$, and tendency to significance factor Central (M = 1.71, SD = .272), t(9) = -2.25, p = .51. Moreover, from the analysis of the open questions emerged that what mostly caused the sickness to participants were the movements of the camera.

3. CONCLUSIONS

The present work underlines the importance of the UCD to develop VR content (Hassenzahl et al., 2006), and to increase the UX. In our case, the cybersickness generate from the 360° video was the main obstacle to overcome, for this reason we conducted an UX test to ensure that the content would not generate any kind of uncomfortableness to participants.

4. REFERENCES

Hassenzahl, M, and Tractinsky, N, (2006). User experience-a research agenda. *Behaviour & information technology*, *25*(2), 91-97.

Kolski, C, Uster, G, Robert, JM, Oliveira, K, and David, B, (2011). Interaction in mobility: the evaluation of interactive systems used by travellers in transportation contexts. In *International Conference on Human-Computer Interaction* (pp. 301-310). Springer, Berlin, Heidelberg.

Mao, JY, Vdredenburg, K, Smith, PW, an Carey, T. (2005). The state of user-centered design practice. *Communications of the ACM*, *48*(3), 105-109.

Triberti, S, Kelders, SM, and Gaggioli, A, (2018). User engagement. In *eHealth Research, Theory and Development* (pp. 271-289). Routledge.

Effects of Personalized Games on Balance in Children with Cerebral Palsy

Kachmar O [1], Kushnir A[2], Helland K[3], Fedchyshyn B[4], Ablikova I[5]

[1 2 4 5] Elita Rehabilitation Center,
Lviv, UKRAINE

[3] HuginTech,
Oslo, NORWAY

[1]*okachmar@ic.reha.lviv.ua*, [2] *anna@ic.reha.lviv.ua*, [3] *kjetil@hugintech.com*, [4]*bohdana.fedchyshyn@gmail.com*, [5]*iryna.ablikova@gmail.com*

[1 2 3 4 5]*lviv.kozyavkin.com/eng*, [3]*hugintech.com*

ABSTRACT

Introduction: Impaired balance is often observed in children with cerebral palsy (CP). Promising results of serious games for balance training have been reported by different research groups. Serious games have positive effects not only on balance but also on motivation. The purpose of the study was to evaluate the effects of a two-week practice with personalised balance games on balancing functions in children with CP.

Materials and methods: This study was conducted on 25 children with CP, aged 5 to 18 years. Participants were randomly selected for experimental or control groups. All children received 8-9 game sessions, 150-160 minutes in general, during two weeks. The experimental group used an online platform with personalised balance games. Features of the platform allow customization of the settings of the games according to the player's abilities. The control group played commercial Nintendo Wii games. The primary outcome measure was a Trunk Control Measurement Scale (TCMS). The secondary outcome measures included the Timed Up & Go Test (TUG), Center of Pressure Path Length (COP-PL), and Dynamic Balance Test (DBT).

Results: TCMS scores increased by 4.5 points (SD = 3.5, $p<0.05$), and DBT results improved by 0.88 points (IQR = 1.03, $p<0.05$) after two weeks of training in the experimental group. These scores did not achieve statistical significance in the control group. TUG and COP-PL results did not change in both groups.

Conclusion: We observed an increase in balance function, particularly sitting and dynamic balance, in participants with CP after a two-week practice with personalised computer games.

1. INTRODUCTION

Balance is the ability to maintain a posture that depends on the central neural system's complex interaction, muscles, strength, proprioception, positioning, vision, and the vestibular system (Niiler, 2018). Impairment of balance is often observed in children with cerebral palsy (CP). Promising results of serious games for balance training have been reported by different research groups. Serious games have positive effects not only on balance but also on the players' engagement.

CP is not only a motor disorder. It is accompanied by disturbances of sensation, perception, cognition, communication, behaviour, and epilepsy (Rosenbaum et al., 2018). To achieve the effective motor learning of new skills, the games need to be adjusted to the child's motor and mental development level.

This study aimed to assess balance function changes in children with CP after two-week practice with personalized computer games.

2. MATERIALS AND METHODS

2.1 Participants

Children who were admitted to a tertiary care rehabilitation clinic were invited. Inclusion criteria were that the children had to be 5 to 18 years of age, diagnosed with CP, and classified as level I, II, or III on the Gross Motor Function Classification System (GMFCS). Exclusion criteria included uncontrolled seizures, severe intellectual disability, or uncooperative behaviour.

Children were randomly assigned either to the experimental or control group. The experimental group used personalized balance games. The control group played Nintendo Wii games using a handheld Wii Remote. Both groups received the same background rehabilitation treatment.

A total of 26 children were recruited, with 13 in each group. One child from the control group failed to finish the study due to somatic illness.

2.2 Intervention

For two weeks, all participants participated in 8-9 game sessions, lasting 15-20 minutes each, 150-160 minutes in general.

Participants from the experimental group played personalized balance games for children with motor disabilities. Children from the control group played Nintendo Wii Sports and Wii Sports Resort games with the handheld Wii Remote.

2.2.1 Personalized balance games.

The balance games used in this study are available on the online platform, which allows adjusting the game settings and monitoring the player’s progress. The platform analyses each child's previous performance, tracks ongoing performance, and suggests a suitable difficulty level for each user in a particular game. The physical therapist or caregiver can customize game levels.

2.3 Outcome measures

The Trunk Control Measurement Scale (TCMS) was the primary outcome measure. TCMS is a clinical test to assess sitting balance in children with CP (Heyrman et al., 2011).

The Timed Up & Go (TUG) test is a clinical tool that is used to evaluate functional mobility in children with CP (Carey et al., 2016).

The Center of Pressure Path Length (COP-PL) was measured using the Static Balance Assessment Tool, a component of the platform developed for measuring basic stabilometry parameters (Chiari, 2009). This tool calculates the displacement of the center of pressure while a person is standing still on the Nintendo Wii Balance Board.

The Dynamic Balance Test (DBT) is another diagnostic tool integrated into the platform. It measures the ability of the child to shift their body weight precisely.

2.3 Statistical analysis

For variables with normal distribution, parametric statistics were used, and pre-post differences were calculated using the paired sample t-test. Median values described variables that failed normality tests with an interquartile range (IQR). Differences between baseline and post-intervention measurements were compared using the Wilcoxon signed-rank test.

3. RESULTS

In the experimental group, a statistically significant improvement of 4.5 points ($SD = 3.5$, $p < 0.05$) in the TCMS score was found. In the control group, there was an improvement of 2.1 points ($SD = 3.38$, $p > 0.05$).

A decrease of the median of the COP-PL by 116 mm (IQR = 671, $p > 0.05$) in the experimental group was noted, and in the control group, it decreased by 117 mm (IQR = 699, $p > 0.05$). These changes were not statistically significant.

Median values of TUG test results decreased by 1 second (IQR = 10, $p > 0.05$) in the experimental group. In the control group, the difference was 0 seconds (IQR= 2, $p > 0.05$). Changes in the TUG score, measured before and after the intervention, were not statistically significant in either the experimental or control group.

DBT median values improved by 0.88 points in the experimental group, which was statistically significant (IQR = 1.03, $p < 0.05$). In the control group, the DBT score change was minus 0.03 points (IQR = 1.59, $p > 0.05$), and this was not statistically significant.

4. CONCLUSIONS

This study shows the improvement of balance in children with CP after two weeks of training with personalized rehabilitation computer games.

A possible reason for the achieved results is that the games were adequately adjusted to the player's motor level, ensuring effective motor learning without losing interest or motivation. These data will help to prepare a future randomized controlled study to evaluate the benefits of personalized computer games on the balance of children with CP.

Acknowledgments: The authors express their gratitude to all families who agreed to participate in this study.

5. REFERENCES

Carey, H., Martin, K., Combs-Miller, S., and Heathcock, J. C, (2016), Reliability and Responsiveness of the Timed Up and Go Test in Children with Cerebral Palsy, *Pediatric physical therapy: the official publication of the Section on Pediatrics of the American Physical Therapy Association*, **28**, *4*, pp. 401–408.

Chiari, L., (2009), Stabilometry, In *Encyclopedia of Neuroscience* (MD Binder, N Hirokawa, U Windhorst, Eds), Springer, Berlin, Heidelberg, p 282.

Heyrman, L., Molenaers, G., Desloovere, K., Verheyden, G., De Cat, J., Monbaliu, E., and Feys, H. (2011), A clinical tool to measure trunk control in children with cerebral palsy: the Trunk Control Measurement Scale, *Res Dev Disabil*, **32**, *6*, pp. 2624–2635.

Niiler T.A., (2018), Assessing dynamic balance in children with cerebral palsy, In: *Cerebral palsy* (F Miller, S Bachrach, N Lennon, et al., Eds), Springer, New York, pp. 1-32.

Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., Bax, M., Damiano, D., Dan, B., & Jacobsson, B. (2007). A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl*, *109*, pp. 8–14.

Virtual Dark Room for Exposure to Intrusive Thoughts

A Francova[1], P Stopkova[2], B Darmova[3], J Kosova[4], I Fajnerova[5]

[1-5]National Institute of Mental Health (NIMH),
Topolová 748, Klecany, CZECHIA

[1]*anna.francova*@nudz.cz, [2]*pavla.stopkova*@nudz.cz, [3]*darmova@gmail.com,* [4]*jirina.kosova@nudz.cz,*
[5]*iveta.fajnerova@nudz.cz*

[1-5]*www.nudz.cz*

ABSTRACT

In this project, we aim to develop and validate a virtual reality exposure therapy (VRET) as a tool for management of excessive worry and intrusive thoughts, that interfere with daily functioning and are characteristic for patients with generalised anxiety disorder, some individuals with obsessive-compulsive disorder (OCD) or other anxiety disorders. We developed a virtual dark room dedicated strictly to exposure therapy of personalised intrusive thoughts. After entering the virtual room, the patient is asked to sit on a virtual chair (matching the position of a real chair in the lab). The patient is exposed to his/her private thoughts (presented in random sequence one after another) and asked to deliberately re-engage in the feared thoughts without avoiding the triggered anxiety. This virtual room enhances the CBT technique "Scheduled Worry Time" used to reduce the overall level of negative intrusive thoughts.

1. INTRODUCTION

Obsessive-compulsive disorder (OCD) is characterized by recurrent, repetitive, and intrusive thoughts or impulses. Some individuals with OCD primarily experience negative intrusive thoughts. In the past, the term primarily obsessional disorder had been used, but it became clear that patients might engage in hidden compulsions such as mental rituals (to try to suppress or neutralize the obsessive thought) that further strengthens anxiety. These thoughts or images often center on negative self-image, somatic or aggressive thoughts or concerns with contamination or control. Intrusive thoughts and excessive worry are very often experienced also by patients with generalized anxiety disorder (GAD) and other anxiety disorders.

Cognitive-behavioral therapy (CBT) including exposure and response prevention (ERP) has been found effective in numerous studies. Existing VR solutions use procedures with specific standardized OCD-inducing stimuli presented uniformly to the patients (e.g., protocol for patients with contamination obsessions). However, OC symptoms of patients without overt compulsions are usually centered around highly specific obsessive thoughts (often focusing on their own family, personal history or current experiences) and anxiety triggers show substantial individual variability. Therapeutic techniques addressing obsessive thoughts represent exposure to them aimed to maximize habituation and/or incorporation of correcting information (Foa and Kozak, 1986), which in turn may reduce anxiety during exposure sessions. For example, exposure to obsessive thoughts had been done by means of a recorded version of patients' thoughts or by imaginal exposures (for a review of therapeutic approaches to OCD, see Hezel and Simpson, 2019). In general, during the exposure, patients are asked to think about the unwanted intrusive thoughts that bother them without trying to do something about them (e.g., to neutralize).

Virtual reality can provide another tool to present patients with obsessive thoughts by writing them down and consequently immersing them in an environment in which these thoughts are displayed in a written form. We developed a virtual environment in which different kinds of OCD-specific items typical for home settings are displayed using virtual glasses (Francová et al., ICVR 2019). This house environment includes a

Dark Room dedicated strictly to exposure therapy for patients with intrusive thoughts hypothesized to elicit anxiety.

2. METHOD

2.1 Technical Equipment

The HTC Vive Pro head-mounted display is used for immersing the participant into the VR experience, providing accurate tracking of the person's head and hand movements. The participant uses a teleporter (touchpad of the controllers) to move through the virtual house to reach the dark room and the trigger button to interact with the environmental features (e.g. doors, chairs). This interactive approach is used to increase the feeling of presence in the virtual environment prior to exposure. The view on the screen is presented from a first-person perspective with the patient seeing virtual hands instead of controllers he is holding.

2.2 Experimental Design & Procedure

In the current research, we aim to validate a virtual environment created using game engine Unity®Pro software that is designed specifically for intrusive thoughts exposure. The aim of the current pilot study is to explore the efficacy of an exposure to obsessive thoughts in terms of the ability to induce anxiety. The VR sessions are part of the activities patients perform during their treatment in NIMH and their goal is to enhance standard CBT program. The Dark Room is based on the CBT activity called Scheduled Worry Time, during which the patients learn to recognize negative worrying thoughts, postpone the engagement with them during the day and re-engage with those worrying thoughts intentionally and on purpose at the planned worry period (McGowan & Behar, 2012).

After entering the virtual lab and signing a written consent, patients are asked to write down a list of subjectively relevant intrusive thoughts to the text document. Their amount and intensity (the level of provoked subjective discomfort) increases between the sessions. The therapist can set the duration by manipulating the fade and display time of the statements (set for single statement). After putting on the headset and controllers, the patient is instructed to walk through the virtual house and to enter the Dark Room. There is a virtual chair matching the position of a real chair located in the lab which is moved to the patient so he/she can sit down comfortably. Then, the sequence of written thoughts is started with statements placed in random order with random breaks duration from 0.3 to 2 seconds. The statements are moving closer to the patient one by one from different corners of the room. By flying towards him/her, their size is increasing. The color of the words vary in hue (shades of red, orange and yellow). When the sequence is over, the therapist can repeat it multiple times by pressing the key "R".

Figure 1. *Illustration of the content and form of visualization of the abstract thoughts.*

During the exposure, patients are asked to observe the flying thoughts as they come and go, without avoiding the triggered anxiety. They are told that if the anxiety is unbearable, they can close the eyes/avert the gaze, but they should inform us about it. During the pilot study, the patients are not instructed to use specific distraction or mindfulness-based strategy. After the first session, all patients are asked to fill in the questionnaires assessing the sense of presence (Slater-Usoh-Steed Presence Questionnaire; SUSPQ, score ranging from 6 to 42) and simulator sickness (SSQ, total score ranging from 0 to 235). During each session, patients fill in the questionnaire assessing subjective anxiety (Spielberger State-Trait Anxiety Inventory; STAI-6, score ranging from 20 to 80), which is a dependent variable in the study. Before and after the hospitalization, the severity of OC symptoms (The Yale–Brown Obsessive Compulsive Scale; Y-BOCS, score ranging from 0 to 20 for both scales) is assessed by the psychiatrist in patients with OCD.

3. RESULTS

Due to the small sample size (n = 5), only descriptive data are provided. Table 1 provides an overview of the patients' available clinical and demographic data. The subjective anxiety scores from before and after the session in the Dark Room for individual sessions are depicted in Figure 2. So far, five patients suffering from excessive worry and intrusive thoughts (who participated in at least 3 sessions) were included into the pilot study.

Table 1. ***Casuistic data: Demographics, psychiatric and psychometric questionnaires.*** *Legend:Dx-Diagnosis, AD - antidepressants, AP - antipsychotic medication, BZD - benzodiazepines, MS - mood stabilizer; for other abbr. see Methods. Reported scales are measured before/after the exposure.*

Patient	Sex/ Age	Dx.	Medication	Y-BOCS obsessions	Y-BOCS compulsions	illness duration	BDI, BAI	SSQ	SUSPQ
P1	F/32	**F422** F603	AD	15/8	14/6	5	15/12 21/27	18,7	35
P2	M/36	**F422** F412	AD, BZN	14/8	13/7	5	35/23 26/5	x	x
P3	M/39	**F331** F422 F410	AD, AP	x	x	6	26/4 26/17	3,74	29
P4	M/41	**F331** F411	AD, MS	18/10	19/10	22	17/15 14/18	18,7	25
P5	F/39	**F411** F330	AD, AP	x	x	18	34/22 16/21	x	x

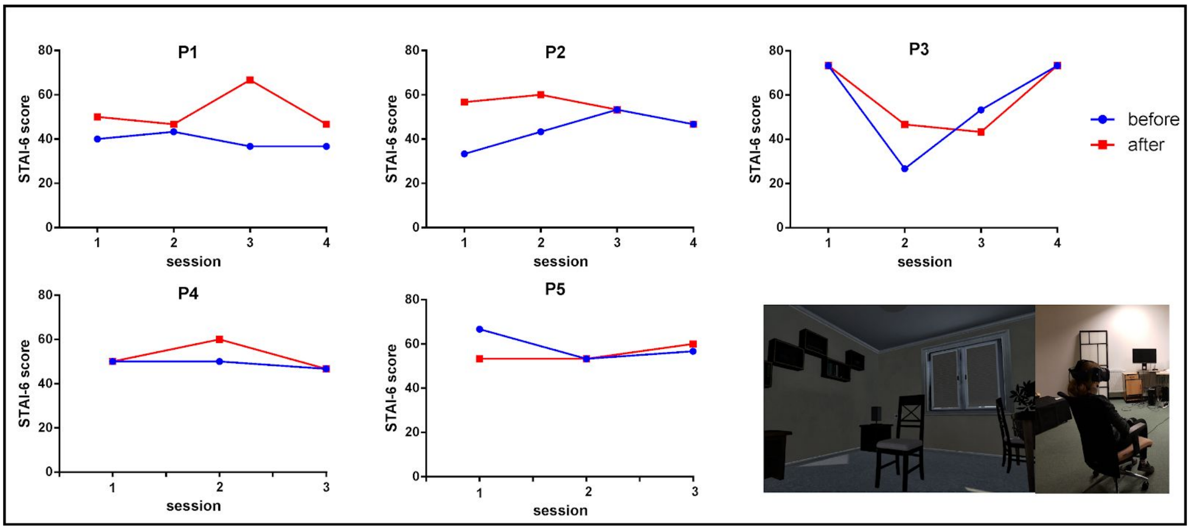


Figure 2. ***Anxiety level evaluated using STAI-6 before and after the exposure.*** *Dark Room seen by the participant after opening the door (the room is brighter for visualization purpose).*

4. DISCUSSION

This pilot study provides the first step towards using VR as a tool for exposure to intrusive thoughts for patients with OCD and other anxiety disorders (e.g., GAD). The main goal of the Dark Room is to create an environment facilitating the experience of intense re-engagement with personalised intrusive thoughts or extensive worries, while restricting possible neutralization or avoidance of such thoughts, with the long term outcome of anxiety reduction. In the future, this approach has to be compared with standard CBT techniques and other approaches (e.g., exposure to thoughts by using less immersive display). Anyway, one of the main benefits of Dark Room is the fact that sessions can be linked to other activities within the virtual house (for example, a patient can manipulate with sharps knives in the kitchen and he/she can work with his/her thoughts shortly after that in the Dark Room nearby). Also, based on patients' reports, exposure to their own thoughts in VR is more intense (VR headset also working as some kind of a "constraint") and the flow of the thoughts (flying towards the participant) could not be so easily visualized using less immersive display. Moreover, the therapist has a better control over the exposure session as the conditions (e.g., the number of the statements) can be manipulated easily. If a patient habituates to a specific circle of thoughts, he/she can gradually start to confront increasingly distressing thoughts.

In this paper, only preliminary descriptive data of 5 patients are presented. Bigger sample with a control group would allow for more precise estimate of the VRET effect. Also, triggered anxiety, thus effectiveness of the exposure sessions, was assessed only by subjective measurement STAI-6. In the future, the physiological response the Dark Room could elicit should be monitored. In the following study, the use of specific distraction strategies will be controlled (e.g., thought suppression or acceptance) and control groups will be included (random allocation). We will also control the urge to neutralize during the programme by adding the questionnaire such as OCI-R including neutralizing subscale. Eye-tracking will be used to ensure the patients are observing the statements so the therapist doesn't have to rely on their verbal report (or direct observation) only.

4. CONCLUSIONS

In this project, we aim to develop and validate a virtual reality exposure therapy (VRET) as a supporting method for management of obsessive thoughts in OCD patients and/or excessive worries in GAD patients. Here we present the preliminary data from a pilot study addressing the usefulness in provocation of anxiety and its application in means of exposure technique.

Acknowledgements: The presented study is supported by the European Regional Development Fund-Project "PharmaBrain" No. CZ.02.1.01/0.0/0.0/16_025/0007444.

5. REFERENCES

Foa, EB, and Kozak, MJ, (1986), Emotional processing of fear: exposure to corrective information, *Psychological bulletin*, *99*(1), pp. 20.

Francová, A, Darmová, B, Stopková, P, Kosová, J, and Fajnerová, I, (2019), Virtual Reality Exposure Therapy in Patients with Obsessive-Compulsive Disorder, *Proc. IEEE International Conference on Virtual Rehabilitation,* pp. 1-2.

Hezel, DM, and Simpson, HB, (2019), Exposure and response prevention for obsessive-compulsive disorder: A review and new directions. *Indian journal of psychiatry*, *61*(Suppl 1), pp. S85.

McGowan, S, and Behar, E, (2012). A preliminary investigation of stimulus control training for worry: Effects on anxiety and insomnia, *Behavior Modification*, 7(1), pp. 90–112.

Walking with immersive virtual reality: the effect of optic flow speed on spatiotemporal gait parameters in people post-stroke

E De Keersmaecker[1 2 3], B Serrien[4], D Rodriguez Cianca[3 5], N Lefeber[1 6], L Cuypers[1 2 3], E Kerckhofs[1 2 3], C Rodriguez-Guerrero[3 5], B Jansen[3 7 8], E Swinnen[1 2 3]

[1]Rehabilitation Research, Department of Physiotherapy, Human Physiology and Anatomy, Vrije Universiteit Brussel, Brussels, BELGIUM

[2]Center for Neurosciences (C4N), Vrije Universiteit Brussel, Brussels, BELGIUM

[3]Brussels Human Robotic Research Center (BruBotics), Vrije Universiteit Brussel, Brussels, BELGIUM

[4]Experimental Anatomy research group, Department of Movement and Sport Sciences, Vrije Universiteit Brussel, Brussels, BELGIUM

[5]Robotics and Multibody Mechanics research group, Department of Mechanics, Vrije Universiteit Brussel and Flanders Make, Brussels, BELGIUM

[6]Department of Rehabilitation Sciences, Faculty of Medicine and Health Sciences, Ghent University, Ghent, BELGIUM

[7]Department of Electronics and Informatics, Engineering Sciences, Vrije Universiteit Brussel, Brussels, BELGIUM

[8]Imec, Leuven, BELGIUM

Emma.De.Keersmaecker@vub.be

ABSTRACT

Optic flow is an important source of visual information while walking. It provides us with information about the speed and direction of self-motion. With the use of virtual reality (VR), the speed of optic flow can be manipulated in order to mediate alterations in human gait patterns. Preliminary results of two stroke patients suggest that small changes in spatiotemporal gait parameters occur when manipulating the optic flow speed during walking on a self-paced treadmill with immersive VR. However, results of the manipulation differed between the two patients and are inconclusive. Further research is necessary with a larger sample size.

1. INTRODUCTION

Post-stroke gait rehabilitation remains a major clinical challenge. Two-thirds of all stroke survivors suffer from walking impairments (Benjamin et al., 2017; Dobkin, 2005), causing them to experience a decrease in activities of daily living, level of participation and quality of life. In order to improve these walking impairments, patients need to be provided with a high-intensive, repetitive and task-specific rehabilitation (Mehrholz, Thomas, & Elsner, 2017). Treadmill training is an example of a repetitive and task-specific gait training and has the potential to enhance neural plasticity – the ability to create permanent structural and functional changes of the brain and spinal cord – which is vital to trigger the learning process of the sensorimotor system (Cano Porras, Siemonsma, Inzelberg, Zeilig, & Plotnik, 2018).

An important source of visual information while walking is optic flow, a pattern of visual motion projected onto the retina of the eye. Optic flow, induced by locomotion, provides us with information about the direction and speed of self-motion (Kang, Kim, Chung, & Hwang, 2012; Salinas, Wilken, & Dingwell, 2017). During treadmill walking, this information is inconsistent with the proprioceptive input of the lower limbs (Kang et al., 2012). Patients are walking on the treadmill, and yet, their environment remains static. With the use of virtual reality (VR), this mismatch can be resolved by letting patients walk in a virtual environment that is moving at matching speed. However, with the purpose to influence the user's gait pattern, the optic flow in this virtual environment can also be manipulated (dos Santos et al., 2016). By manipulating the speed of the optic flow – increased or decreased in relation to the subject's walking speed – there will again be a mismatch between the optic flow and the proprioceptive information of the lower extremities causing the gait pattern to adjust (Kang et al., 2012; Lamontagne, Fung, McFadyen, & Faubert, 2007).

Previous studies in healthy volunteers and neurological patients – which are limited – have shown that gait parameters like walking speed or stride length can be manipulated by changing the optic flow speed during overground (Chou et al., 2009; Lim, 2014) or treadmill walking (Katsavelis, Mukherjee, Decker, & Stergiou, 2010; Lamontagne et al., 2007; Mohler, Thompson, Creem-Regehr, Pick, & Warren, 2007). Results suggest that there is a negative correlation between the speed of the optic flow and the walking speed, indicating that subjects will walk faster at a slower optic flow speed and vice versa. This may indicate that optic flow speed manipulation can be used during walking as a new training strategy to improve the gait function. However, previous studies investigated the effect of optic flow speed over a limited walking time (i.e. 15 minutes). A more in-depth exploration is necessary to determine how such manipulation could be useful for rehabilitation purposes. Therefore, this study incorporated longer walking durations (i.e. 22 minutes) than in current studies to get a better understanding of the influence of 'optic flow' on the gait pattern during treadmill walking post-stroke.

2. METHODOLOGY

2.1 Subjects

Two male chronic stroke survivors (aged 55 and 60 years, respectively 33- and 115-months post-stroke) participated in the experiment (Table 1). The protocol was approved by the Ethics Committee of the University of Brussels (B.U.N. 143201939043) and written consent was obtained prior to participation.

Table 1. Patients characteristics

	Patient 1	Patient 2
Gender	male	male
Age (years)	55	60
Stroke onset (months)	33	115
Paretic side	right	left
FAC score (/5)	4	4
Body Mass (kg)	85	100
Body Height (cm)	191	166

2.2 Experimental setup

The experimental setup contained a head-mounted display (HMD) (Oculus Rift, USA), a 10-camera Vicon motion capture system (Vicon Motion System, USA), and a self-paced treadmill. The treadmill speed was controlled by the natural inclination of the patient while trying to move forward or stand still. The treadmill has a total of two 6-axis force sensors connected to each side of the human user's pelvis through a ball joint that supports a harness. The treadmill's speed is controlled in real time based on the measured interaction forces between the patient and the harness caused by the natural dynamic displacement of the user's center of mass (COM) during walking.

2.3 Procedure

Subjects participated in 4 sessions of walking on a self-paced treadmill, all carried out on separate days. Each session lasted 22 minutes. In the first session, subjects walked on the self-paced treadmill without VR to get used to the treadmill system (control condition). In the following 3 sessions, subjects wore the HMD and walked on the self-paced treadmill while being immersed in the virtual environment representing a park outside. The three VR sessions differed only in the speed of the optic flow: matched, 2 times faster and 2 times slower than the subject's average walking speed during the control condition (baseline walking speed). In the matched condition, the speed of the optic flow in the virtual environment was equal to the subject's baseline walking speed. In the fast condition, the optic flow speed was twice as fast as the subject's baseline walking speed. In the slow condition, the optic flow was twice as slow as the subject's baseline walking speed. The order of the VR conditions was randomized. The first 2 minutes of each VR session had a matching optic flow speed. Thereafter, the optic flow speed was manipulated for the remaining 20 minutes. Subjects were not informed about this manipulation.

2.4 Data processing

Twenty-one minutes of continuous kinematic marker data of the lower limbs were acquired by Vicon Nexus software (Vicon Motion Systems, USA) and used for analysis (the first minute of each trial was omitted). Spatiotemporal gait parameters (i.e. walking speed, step length, stride time, stance time and swing time) were calculated in Python 3.7 (Anaconda Inc., USA).

3. RESULTS

Overall, the temporal gait parameters stance time and swing time were not affected by the optic flow speed manipulation. Only minimal changes over time were seen for these parameters in all conditions and will therefore not be discussed in more detail. Manipulating the optic flow speed in an immersive virtual environment did slightly influence the step length, stride time and walking speed of the two patients. Results per minute (mean with SD) are presented in Figure 1. The manipulation occurred after first walking with a matched optic flow (minute 0 in the graphs) and lasted for the remaining 20 minutes (minute 1 till 20 in the graphs). The session with the slow optic flow speed in patient 1 had to be stopped earlier due to technical problems of the treadmill system. Therefore, results of only 17 minutes of walking with the manipulation are shown.

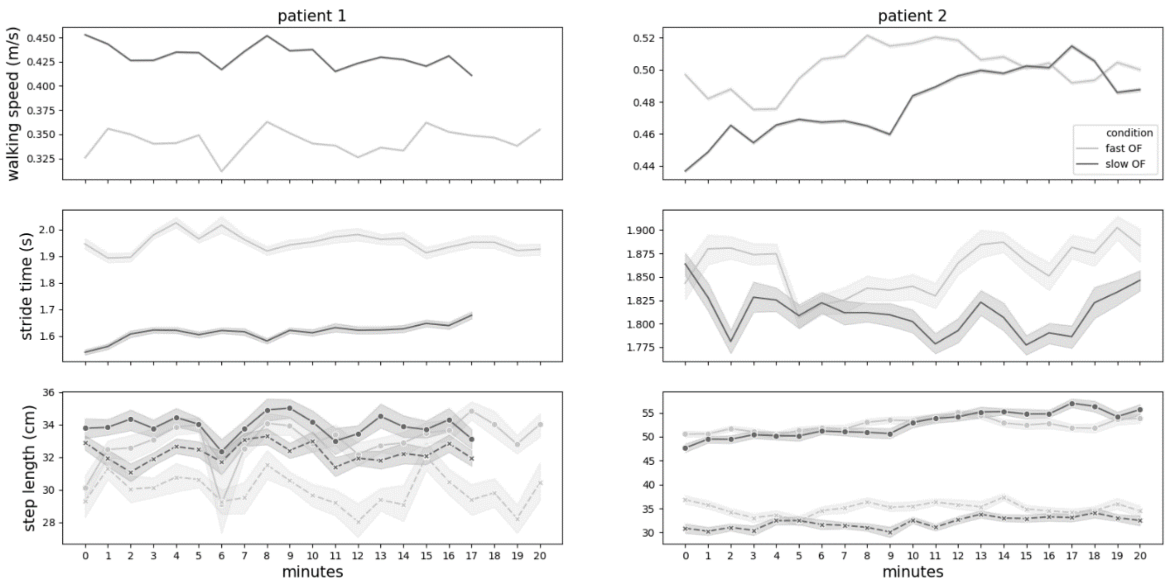


Figure 1. Results of walking speed, stride time and step length per minute (mean with SD) in both patients. Light grey is fast optic flow condition and dark grey is slow optic flow condition. In the bottom graph (step length), the full line with circles represent the paretic leg and the dotted line with crosses the non-paretic leg.

In the first patient (Fig. 1, left graphs), we found a positive relation between walking speed and optic flow speed. When walking with a fast optic flow speed, the walking speed immediately increased with 0.03 m/s with respect to minute 0 (matched optic flow speed) and continued to be higher throughout the 20 minutes, with the exception of minute 6. However, at that moment during the session, the treadmill system was blocked for a short moment and the patient had to stop walking for a few seconds. This slight increase in walking speed was induced by taking longer steps with both the paretic leg (+5 cm) and non-paretic leg (+3 cm) and a shorter stride time (-0.06 s). Walking with a slow optic flow speed, led to a decrease in walking speed of 0.04 m/s with respect to minute 0 (matched optic flow speed). Compared to the fast optic flow speed, these changes in walking speed were more gradual over time and were induced by taking shorter steps with the non-paretic leg (-2 cm) and a longer stride time (+0.14 s).

In patient 2 (Fig. 1, right graphs), a negative relation was found between walking speed and optic flow speed. With a fast optic flow, patient 2 decreased his walking speed with 0.02 m/s with respect to minute 0 (matched optic flow speed). This slight decrease was induced by taking shorter steps with the non-paretic leg (-5 cm) and a longer stride time (+0.04 s). However, after 4 minutes, there was again an increase in walking speed which was induced by an increase in step length and stride time. Walking with a slow optic flow speed, led to a gradual increase in walking speed of 0.07 m/s over time with respect to minute 0 (matched optic flow speed), induced by taking longer steps with both the paretic leg (+9 cm) and non-paretic leg (+3 cm) and a shorter stride time (-0.08 s).

4. CONCLUSIONS

The results of two patients show that small changes in spatiotemporal gait parameters occur when manipulating the optic flow speed with immersive VR while walking on a self-paced treadmill. However, results of the manipulation differed between the two patients and are inconclusive. Important to notice is that these are only preliminary results of two patients and many more patients need to be tested before we can obtain any definitive conclusion about the effects of optic flow speed. An important limitation of this set-up was that the manipulation of the optic flow speed was based on the comfortable walking speed of the patient during the first session. Especially with stroke patients, their physical capabilities can vary greatly from day to day. Consequently, the manipulation was not exactly twice as fast or twice as slow as the patient's walking speed. In the future, the manipulation has to be done in real-time, meaning that the manipulation is based on the comfortable walking speed of the patient on that day.

Acknowledgements: E De Keersmaecker and D Rodriguez-Cianca are both Strategic Basic Research fellows funded by the Research Foundation Flanders (FWO).

5. REFERENCES

Benjamin, E. J., Blaha, M. J., Chiuve, S. E., Cushman, M., Das, S. R., Deo, R., et al. (2017). Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association. *Circulation, 135*(10), e146-e603.

Cano Porras, D., Siemonsma, P., Inzelberg, R., Zeilig, G., & Plotnik, M. (2018). Advantages of virtual reality in the rehabilitation of balance and gait: Systematic review. *Neurology, 90*(22), 1017-1025.

Chou, Y. H., Wagenaar, R. C., Saltzman, E., Giphart, J. E., Young, D., Davidsdottir, R., et al. (2009). Effects of optic flow speed and lateral flow asymmetry on locomotion in younger and older adults: a virtual reality study. *J Gerontol B Psychol Sci Soc Sci, 64*(2), 222-231.

Dobkin, B. H. (2005). Clinical practice. Rehabilitation after stroke. *N Engl J Med, 352*(16), 1677-1684.

dos Santos, L. F., Christ, O., Mate, K., Schmidt, H., Kruger, J., & Dohle, C. (2016). Movement visualisation in virtual reality rehabilitation of the lower limb: a systematic review. *Biomedical Engineering Online, 15*.

Kang, H. K., Kim, Y., Chung, Y., & Hwang, S. (2012). Effects of treadmill training with optic flow on balance and gait in individuals following stroke: randomized controlled trials. *Clinical Rehabilitation, 26*(3), 246-255.

Katsavelis, D., Mukherjee, M., Decker, L., & Stergiou, N. (2010). The effect of virtual reality on gait variability. *Nonlinear Dynamics Psychol Life Sci, 14*(3), 239-256.

Lamontagne, A., Fung, J., McFadyen, B. J., & Faubert, J. (2007). Modulation of walking speed by changing optic flow in persons with stroke. *Journal of Neuroengineering and Rehabilitation, 4*.

Lim, H. (2014). Effect of the Modulation of Optic Flow Speed on Gait Parameters in Children with Hemiplegic Cerebral Palsy. *Journal of Physical Therapy Science, 26*(1), 145-148.

Mehrholz, J., Thomas, S., & Elsner, B. (2017). Treadmill training and body weight support for walking after stroke. *Cochrane Database Syst Rev, 8*, Cd002840.

Mohler, B. J., Thompson, W. B., Creem-Regehr, S. H., Pick, H. L., & Warren, W. H. (2007). Visual flow influences gait transition speed and preferred walking speed. *Experimental Brain Research, 181*(2), 221-228.

Salinas, M. M., Wilken, J. M., & Dingwell, J. B. (2017). How humans use visual optic flow to regulate stepping during walking. *Gait Posture, 57*, 15-20.

An Integrative Review of Rehabilitation Training based on Virtual Reality for Children with Cerebral Palsy

S R Park[1], S G Kim[1], K J Lee[1], G E Lee[2], J H Jung[2], S W Oh[2], I K Cho[2], S G On[2], H K Kim[2], H. Kweon[3]

[1]Department of Rehabilitation & Assistive Technology,
[2]Department of Rehabilitation Medicine,
[3]Assistive Technology Research Team for Independent Living,
National Rehabilitation Center, 58 Samgaksan-ro, Seoul, Republic of Korea, 01022

[1]soras1005@korea.kr, [2]fbkhk@korea.kr, [3]hskweon@korea.kr

[1, 2, 3]*www.nrc.go.kr*

ABSTRACT

The purpose of this study is to derive clinical basis of virtual reality based rehabilitation training for children with cerebral palsy by integrative review and analyze. For the integrative literature review, the recent 14 years (2004.1 to 2018.9) of journals were searched through PubMed for the selection of literature to be analyzed. In addition, the five-stage review method presented by Whittemore & Knafl was used. According to the literature search, there were a total of 20 papers that conducted virtual reality based rehabilitation training on children with cerebral palsy. 10 papers were showed that compared to traditional training method, virtual reality based training methods improved the gross motor function and balance of children with cerebral palsy, and 3 papers reported that it was effective when the NDT(Neuro Development Treatment) or tDCS (transcranial Direct Current Stimulation) and virtual reality-based rehabilitation training were combined. In the other 2 papers, VR-based training has improved children's active participation. The integrative review showed potential for effect of virtual reality based rehabilitation training for children with cerebral palsy. Based on result of this study, we need to develop a virtual reality-based rehabilitation training method for children with cerebral palsy.

1. INTRODUCTION

Gait disorders caused by damage to the central nervous system have a significant impact on the quality of life of the patient. This can be improved through a large amount of repetitive, task-oriented training and appropriate feedback under the active participation of patients, but in the case of children, treatment at clinical sites is difficult. The virtual reality system based rehabilitation treatment solves these difficulties at the clinical site. Virtual reality systems can motivate children to participate voluntarily through game elements, provide various sensory feedback while minimizing therapist intervention, and enable quantitative measurement of performance and movement during treatment using sensors. However, research into the effects is insufficient. The purpose of this study was to investigate the effects of virtual reality-based in children with cerebral palsy through a literature survey.

2. METHOD

Our review searched articles published between January 2004 and September 2018 from database PubMed. Later, our search has been conducted on five-stage, described by Whittemore & Knafl.

The keywords was “cerebral palsy” , “virtual reality”, ”motor learning”, ” rehabilitation” , “dependent Ambulation”,” “gait”, “ mobility”.

3. RESULTS

A total of 20 papers were conducted on children with cerebral palsy.

Kinect Xbox 360 (Microsoft, USA) was the most frequently used training method in 5 studies(Table 1).

Table 1. *The using devices for VR.*

Training method	Study(n)
Kinect Xbox 360(Microsoft, USA)	5
IREX(GestureTek, USA)	2
R-Mill(Forcelink, Netherlands)	3
GRAIL(Motek, Netherlands)	2
Lokomat(Hocoma AG, Switzerland)	2
Wii(Nintendo, Japan)	2
RA CP system(Burdea, USA)	1
Smartphone	1
Kinect Xbox 360+IREX	1
No information	1

To evaluate children's motor and function, GMFM and PBS were used in most studies. ADL was assessed using Wee-FIM(Wee-Functional Independence Measure), AMPS(Assessment or Motor and Process Skills) and ADL(Activities of Daily Living) .Two studies were used questionnaires to assess satisfaction and quality of life.

As a result of gait training using VR technology, 10 studies reported that virtual reality-based rehabilitation training improved the function and balance of children with cerebral palsy(Table 2). Three papers reported that it was effective when the NDT(Neuro Development Treatment) or tDCS (transcranial Direct Current Stimulation) and virtual reality-based rehabilitation training were combined. In the other two papers, VR-based training has improved children's active participation.

Table 2. *The effect of rehabilitation training using VR.*

Study (first author, year)	Characteristics of patients		Study design	Training Method	Intervention (times a week /total sessions)	Outcome
	Diagnosis	Age (year)				
Jung SH, 2018	CP	8-10	Case study	Kinect Xbox 360	3/12	PBS, TUG, FMS, 6MWT
Gagliardi C, 2018	CP	7-16	Pilot study	GRAIL	5/20	Walking pattern, 6MWT
Van Gelder L. 2017	CP	6-16	RCT	GRAIL+feedback	-	Hip and Knee joint angle
Fang Fu, 2016	CP	4-11	Pretest-Posttest	Non-immersive VR	-	DFPI
Cho, 2016	CP	9-10	RCT	Wii	3/24	GMFM, PBS
Collange Grecco LA, 2015	CP	5-10	RCT	Kinect Xbox 360	5/10	Gait speed & cadence, GMFM
Luna Oliva, 2013	CP	4-11	Pilot study	Kinect Xbox 360	2/16	GMFM, AMPS, PRT, 10MWT
Burdea, 2013	CP	7-12	Case study	RA CP system	3/36	Ankle kinematics, speed, edurance
Brien, 2011	CP	13-16	Pretest-Posttest	IREX	5/5	CB&M, 6MWT
Sveistrup H, 2004	CP, TBI	-	RCT	IREX	-	BBS, Functional mobility

RCT, randomized controlled trial; PBS, pediatric balance scale; TUG, timed up and go test; FMS, functional mobility scale; 6MWT, 6-meter walk test; DFPI, dynamic foot pressure index; GMFM, Gross motor functional measure; AMPS, assessment of motor and process skills; PRT, pediatric reach test; 10MWT, 10m walk test; CB&M, community balance & mobility scale; BBS, berg balance scale

4. CONCLUSIONS

The study showed the possibility of virtual reality-based rehabilitation training for children with cerebral palsy. Virtual reality technology helped improve children's participation in treatment and motivate them, and was able to give feedback on accurate walking behavior. In the future, additional research will be needed to utilize virtual reality technology as an effective means of rehabilitation training for children with cerebral palsy.

Acknowledgements: This research was supported by a grant (18-A-02) of the Korea National Rehabilitation Center, Ministry of Health & Welfare.

5. REFERENCES

Reid DT, (2004), The influence of virtual reality on playfulness in children with cerebral palsy: a pilot study, *Occup Ther*, 11, pp. 131–144.

Tarakci D, Ersoz Huseyinsinoglu B, Tarakci E, Razak Ozdincler A, (2016), The Effects of Nintendo Wii‐ Fit Video Games on Balance in Children with Mild Cerebral Palsy, *Pediatrics International.*

Cho C, Hwang W, Hwang S, Chung Y, (2016), Treadmill training with virtual reality improves gait, balance, and muscle strength in children with cerebral palsy, *The Tohoku journal of experimental medicine*, 238, pp. 213-218.

AlSaif AA, Alsenany S, (2015), Effects of interactive games on motor performance in children with spastic cerebral palsy, *Journal of physical therapy science*, 27, pp. 2001.

Grecco LAC, Duarte NdAC, Mendonca ME, Galli M, Fregni F, Oliveira CS, (2015), Effects of anodal transcranial direct current stimulation combined with virtual reality for improving gait in children with spastic diparetic cerebral palsy: a pilot, randomized, controlled, double-blind, clinical trial, *Clinical rehabilitation*, 29, pp. 1212-1223.

Sharan D, Ajeesh P, Rameshkumar R, Mathankumar M, Paulina RJ, Manjula M, (2012), Virtual reality based therapy for post operative rehabilitation of children with cerebral palsy, *Work*, 41, pp. 3612-3615.

Jaume-i-Capo A, Martinez-Bueso P, Moya-Alcover B, Varona J, (2014), Interactive rehabilitation system for improvement of balance therapies in people with cerebral palsy, *IEEE transactions on neural systems and rehabilitation engineering*, 22, pp. 419-427.

Jelsma J, Pronk M, Ferguson G, Jelsma-Smit D, (2013), The effect of the Nintendo Wii Fit on balance control and gross motor function of children with spastic hemiplegic cerebral palsy, *Developmental neurorehabilitation,* 16, pp. 27-37.

Luna-Oliva L, Ortiz-Gutierrez RM, Cano-de la Cuerda R, Piedrola RM, Alguacil-Diego IM, Sanchez-Camarero C, et al, (2013), Kinect Xbox 360 as a therapeutic modality for children with cerebral palsy in a school environment: a preliminary study, *NeuroRehabilitation*, 33, pp. 513-521.

Ramstrand N, Lygnegard F, (2012), Can balance in children with cerebral palsy improve through use of an activity promoting computer game?, *Technology and Health Care*, 20, pp. 531-540.

Pavao SL, Arnoni JLB, Oliveira AKCd, Rocha NACF, (2014), Impact of a virtual reality-based intervention on motor performance and balance of a child with cerebral palsy: a case study, *Revista Paulista de Pediatria*, 32, pp. 389-394.

Burdea GC, Cioi D, Kale A, Janes WE, Ross SA, Engsberg JR, (2013), Robotics and gaming to improve ankle strength, motor control, and function in children with cerebral palsy—A case study series, *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 21, pp. 165-173.

Tavares CN, Carbonero FC, Finamore PdS, Kós RS, (2013), Uso do Nintendo Wii para reabilitacao de criancas com paralisia cerebral: estudo de caso, *Rev Neurocienc*, 21, pp. 286-93.

Brien M, Sveistrup H, (2011), An intensive virtual reality program improves functional balance and mobility of adolescents with cerebral palsy, *Pediatric Physical Therapy*, 23, pp. 258-266.

Patritti BL, Sicari M, Deming LC, Romaguera F, Pelliccio MM, Kasi P, et al, (2010), The role of augmented feedback in pediatric robotic-assisted gait training: A case series, *Technology and Disability*, 22, pp. 215-27.

Deutsch JE, Borbely M, Filler J, Huhn K, Guarrera-Bowlby P, (2008), Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy, *Physical therapy*, 88, pp. 1196-1207.

neomento–Modern Virtual Reality System for Psychotherapy

Adam Streck[1], Philipp Stepnicka[2], Robin Frank[3], Jens Klaubert[4], Thomas Wolbers[5]

[1234]Aging and Cognition group, German Centre for Neurodegenerative Diseases e.v.
Charitéplatz 1, Virchowweg 6, 10117, Berlin, Germany

[5]Aging and Cognition group, German Centre for Neurodegenerative Diseases e.v.
Leipziger Straße 44, Haus 64, 39120, Magdeburg, Germany

[1]*adam.streck@dzne.de,* [5]*thomas.wolbers@dzne.de*

[12345]*www.dzne.de*

ABSTRACT

The neomento project focuses on development of high-fidelity virtual environments for virtual reality exposure therapy (VRET). Within the project we have developed the neomento SAD software targeting the social anxiety disorder (ICD-10 F40.1). This is done by providing a dual interface. A virtual environment is presented to the patient, who has to progress through a particular set of challenges, *e.g.* give a presentation, take a train, etc. Meanwhile the therapist is provided a representation of what the patient sees together with a control interface allowing them to adjust the hostility of the environment, the complexity of challenges and to lead dialogues with the patients through virtual characters. Preliminary results show a high level of adaptation and compliance with this software from clinicians as well as patients.

1. INTRODUCTION

Mental disorders, like anxiety disorders, are a massive, world-wide problem and constitute an enormous challenge for the healthcare systems everywhere (Olesen et al., 2012). Patients are currently facing long waiting periods (about five months in Germany; Bundespsychotherapeutenkammer, 2018) before being admitted to treatment, which may lead to prolonged suffering, as well as a high number of untreated cases (current coverage of 21% in social phobia compared to 40% for most disorders; Issakidis et al., 2004). Traditional exposure therapy–in which the patients are repeatedly exposed to patient specific stimuli causing stress, fear, or craving–is an effective method, however, it is often prohibitively difficult and expensive (Kampmann et al., 2016).

The neomento project aims to address this issue by employing a VR based software solution for the therapy of anxiety disorders. To this end, we create a virtual representation of realistic situations that are then presented to the patient in the form of a VR experience while being controlled by the therapist. This approach considerably decreases the financial and time expense to the therapist (Olesen et al., 2012) while maintaining the proven effectiveness of exposure therapy (Bouchard et al., 2017; Meyerbroeker et al., 2013).

The efficacy of VR based treatment in psychiatric disorders has been tested in clinical trials over the last few years, showing promise in the treatment of anxiety disorders (Bouchard et al., 2017; Kampmann et al., 2016; Meyerbroeker et al., 2013; Opriş et al., 2012; Turner & Casey, 2014) while demonstrating more efficiency to use than conventional treatments (Bouchard et al., 2017). Generally, VRET is comparable in effect to *in vivo* exposure therapy (iVET) and can be complemented to greater effect by cognitive behavioral therapy as well as other techniques (Riva et al., 2019).

While the VRET approach has been already developed and successfully demonstrated in the past (Bouchard et al., 2017; Kampmann et al., 2016; Meyerbroeker et al., 2013; Opriş et al., 2012; Turner & Casey, 2014), mass adoption has so far not occurred. This is arguably due to two factors: i) until recently the cost of VR devices has been disproportionately high and ii) the quality and functionality of the simulations have not been sufficient to persuade either the therapists or the patients. While the first problem has been alleviated by the massive drop in the cost of VR devices in recent years (Wallach et al., 2011), the second problem remains. The aim of the neomento project is to combine multiple areas of human-computer interaction research in order to maximize the persuasiveness, effectiveness and usability of the method, thus allowing for practical use.

2. IMPLEMENTATION

In the following, we present our system. We have developed our technology with the following aims: 1) High visual quality; 2) Minimum of intrusions that could break presence; 3) Immersive social interactions; 4) Minimal cybersickness; 5) High usability (and consequently increasing adoption and decreasing the risk of user error).

2.2. Technology and configuration

The neomento system is currently developed to be used with the Vive Pro Eye VR system. This system has been chosen because it provides very high visual clarity while still being reasonably affordable. The eye-tracking component of the headset provides guided calibration of the interpupillary distance (IPD), as well as the overall position, which is important for less tech savvy users as they have to adjust the IPD and the headset themselves.

The system is designed to provide the therapist with the full control of the environment for the whole duration of the exposure. The VR experience is rendered on the connected PC, where the therapist is provided with a control screen, see Fig. 1.The individual actions of both the therapist and the patient are stored during the session together with the session configuration. During the exposure the patient also reports to the therapist their subjective units of distress (SUDs) which are displayed in the UI and also can be later recovered by the therapist.

2.2. Interaction system

Our system had to solve the following challenges for the patient:

How to navigate: We recognized that it is necessary to provide the user the ability to move on their own volition in order to control how they approach a difficult task. At the same time, all the known methods of movement in a VR space have negative effects on both immersion and cybersickness (Rizzo & Koenig, 2017). To this end, we have implemented a linear movement and teleportation to let the therapist decide on their own.

How to interact with the environment: VR sets traditionally offer generic hand-held controllers to interact with the environment. Many interactive experiences represent these in the form of a virtual hand, however, this can quickly become immersion breaking due to the uncanny valley effect (Stein & Ohler, 2017). Multiple researchers have observed that a discrepancy between the visual and the held representation of the controller are usually not perceived by the user. We have therefore developed two versions of controller representations—a presenter and a smartphone—both of which can interact using either proximity (*e.g.* by placing the phone controller close to an NFC virtual object) or using buttons (*e.g.* to start a presentation).

How to communicate with the virtual characters: In order to create appropriate social scenarios it was important to interact with the virtual characters in a consistent and realistic manner. We believe that it is not possible to fully automate the process, consequently, we created a system where the therapist can set the mood and progress through a conversation tree by manually setting responses to the patient.

2.3 Scenarios

We have developed two different sets of scenarios to serve different purposes. Both of these include multiple different scenes, each of which is highly configurable, allowing the therapist to tailor the experience to the needs of the particular patient. The scenarios belong to one of the two categories:

Office Space: This category encompasses the scenarios focused on social interaction. We have developed multiple scenarios for public speaking, with either pre-defined presentations or the ability to import presentations from the user. Secondly we provide a scenario for interaction with services, represented by a library environment (which further increases the stress of speaking). Here are multiple challenges presented to the patient in this environment, for example requesting a book on an embarrassing topic.

Public Space: Here we combine the social interaction with presence in open/closed spaces. The first main challenge is walking through a square. This scenario combines the stress in being in a wide open space with the challenges that can be encountered in public, such as being approached by a stranger or by police. The second scenario is travelling by subway. Here the patient is conflicted with close-spaced environments like an elevator, subway station, subway train in the tunnel while encountering socially frustrating situations such as problems with a ticket machine with people watching.

3. EVALUATION

For a usability evaluation, 15 participants were allocated randomly to VR scenarios. The therapist user group was on average 35 years old and consisted of nine psychologists, three psychotherapists, one psychiatric, one physician, and one appropriate assistant. Therapists had no experience with the software (n = 9) or only had a short introduction/presentation of the software at a development stage in the past (n = 6).

Figure 1. *Alpha version of the public square scenario: The virtual environment is presented to the patient and mirrored to the therapist through a screen. The patient sees their controller in the form of a phone (bottom). The therapist can control the environment using a specifically developed user interface (left).*

After the first usage of the software, therapists answered questions about their experience on a five-point Likert scale, the results are reported descriptively in Fig. 2. In a following free-text questionnaire, therapists stated that they had no problems using the software even though they were using it for the first time. The operation was mainly clear and quite intuitive. Minor bugs regarding the software design and a lack of experience, as well as knowledge of the functionality of the software were reported in the debriefing questionnaire. However, the therapists were confident that the use of the software will be very easy to learn even without external support.

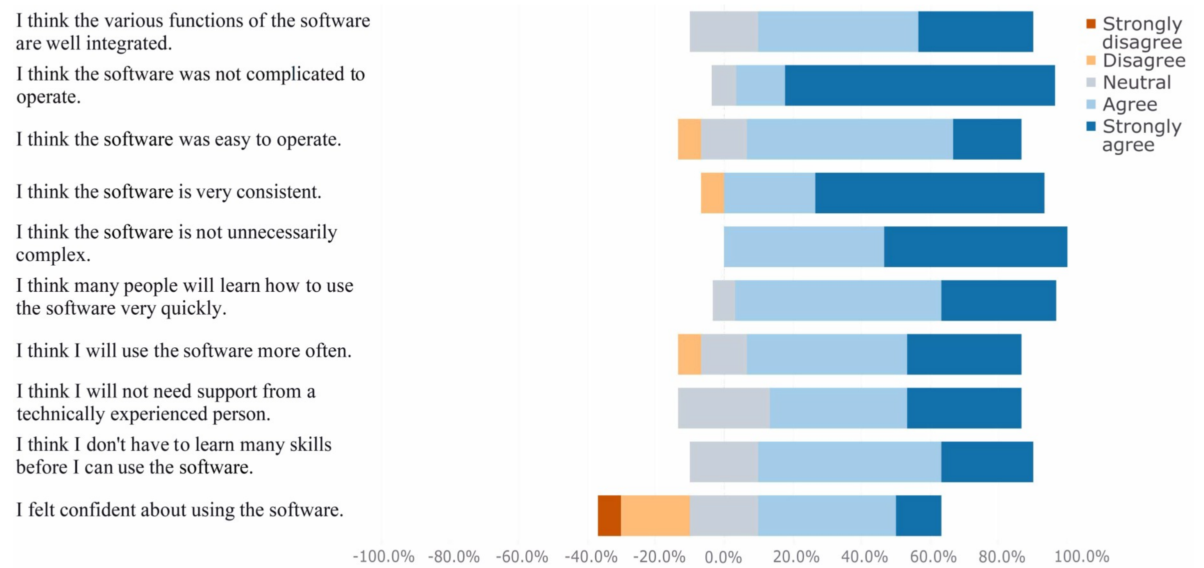


Figure 2. *Questions (left) and according responses (right, colored) from a usability evaluation survey in 15 participants. One missing response was excluded from the chart.*

4. CONCLUSIONS

With increased advances in VR technology, a wider range of applications, and lower costs of devices (Bouchard et al., 2017), VRET has become a more realistic option for widespread use. The neomento software solution is an innovative and efficient alternative for anxiety treatment using these advanced VR technologies that can now immerse users in an almost photo-realistic environment. Using this approach, the time and effort of personnel will be significantly lower with VRET compared to iVET. Other advantages are the controllability of the exposure and a possible individual adaptation of the scenario to the patient's needs. In addition, the presentation of fear evoking stimuli and situations in the virtual environment will be experienced as less invasive than in the real world which enhances the overall motivation and acceptance for therapy.

In a usability evaluation, we have shown that the neomento software was easy to use, intuitive, and well-received by the therapist user group. Therapists were able to use and control a range of functions to the benefit of their patients' treatment. With respect to the importance of usability (Bouchard et al., 2017), the software also shows high user-friendliness as well as large acceptance in the user group. To this end, the software was developed with a simple and clear user interface that makes it possible to exploit the exposure experience more.

Realism is important to the success of VRET sessions: If this approach is to be comparable in effect to iVET, the experience needs to resemble real-life enough for the patient that it properly stimulates anxiety to a similar degree as real-life events trigger it (Poeschl & Doering, 2015). Within the neomento software, the implementation of lifelike characters and a broad variety of characters' dialogues ensure realistic as well as more complex social interactions during the exposure and will enhance treatment outcomes.

Acknowledgments: We would like to acknowledge the work of our cooperating clinical partner (Schön Klinik Bad Arolsen, Germany) with consultations and testing by specialists. Further, we would like to acknowledge the work by the students and collaborators from the Charité - Universitätsmedizin Berlin, Germany.

5. REFERENCES

Bouchard, S., Dumoulin, S., Robillard, G., Guitard, T., Klinger, É., Forget, H., Loranger, C., & Roucaut, F. X. (2017). Virtual reality compared with exposure in the treatment of social anxiety disorder: a three-arm randomised controlled trial. *The British Journal of Psychiatry: The Journal of Mental Science*, *210*(4), 276–283.

Bundespsychotherapeutenkammer. (2018). *Ein Jahr nach der Reform der Psychotherapie-Richtlinie, Wartezeiten 2018*.

Issakidis, C., Sanderson, K., Corry, J., Andrews, G., & Lapsley, H. (2004). Modelling the population cost-effectiveness of current and evidence-based optimal treatment for anxiety disorders. *Psychological Medicine*, *34*(1), 19–35.

Kampmann, I. L., Emmelkamp, P. M. G., & Morina, N. (2016). Meta-analysis of technology-assisted interventions for social anxiety disorder. *Journal of Anxiety Disorders*, *42*, 71–84.

Meyerbroeker, K., Morina, N., Kerkhof, G. A., & Emmelkamp, P. M. G. (2013). Virtual reality exposure therapy does not provide any additional value in agoraphobic patients: a randomized controlled trial. *Psychotherapy and Psychosomatics*, *82*(3), 170–176.

Olesen, J., Gustavsson, A., Svensson, M., Wittchen, H.-U., Jönsson, B., CDBE2010 study group, & European Brain Council. (2012). The economic cost of brain disorders in Europe. *European Journal of Neurology: The Official Journal of the European Federation of Neurological Societies*, *19*(1), 155–162.

Opriş, D., Pintea, S., García-Palacios, A., Botella, C., Szamosközi, Ş., & David, D. (2012). Virtual reality exposure therapy in anxiety disorders: a quantitative meta-analysis. *Depression and Anxiety*, *29*(2), 85–93.

Poeschl, S., & Doering, N. (2015). Measuring Co-Presence and Social Presence in Virtual Environments - Psychometric Construction of a German Scale for a Fear of Public Speaking Scenario. *Studies in Health Technology and Informatics*, *219*, 58–63.

Riva, G., Wiederhold, B. K., & Mantovani, F. (2019). Neuroscience of Virtual Reality: From Virtual Exposure to Embodied Medicine. *Cyberpsychology, Behavior and Social Networking*, *22*(1), 82–96.

Rizzo, A. S., & Koenig, S. T. (2017). Is clinical virtual reality ready for primetime? *Neuropsychology*, *31*(8), 877–899.

Stein, J.-P., & Ohler, P. (2017). Venturing into the uncanny valley of mind—The influence of mind attribution on the acceptance of human-like characters in a virtual reality setting. In *Cognition* (Vol. 160, pp. 43–50).

Turner, W. A., & Casey, L. M. (2014). Outcomes associated with virtual reality in psychological interventions: where are we now? *Clinical Psychology Review*, *34*(8), 634–644.

Wallach, H. S., Safir, M. P., & Bar-Zvi, M. (2011). Virtual reality exposure versus cognitive restructuring for treatment of public speaking anxiety: a pilot study. *The Israel Journal of Psychiatry and Related Sciences*, *48*(2), 91–97.

MobVIP: An Assistive Technology to Improve Mobility of Visually Impaired

A Karkouti[1], E Kani-Zabihi[2], M M Nasralla[3], D Sobnath[4], I U Rehman[5]

[1,2,5] School of Computing and Engineering, University of West London,
St Mary, Ealing, London, UK

[3]Communications and Networks Engineering, Prince Sultan University,
Riyadh, Saudi Arabia

[4]Research, Innovation and Enterprise, Solent University,
E Park Terrace, Southampton, UK

[2]*elahe.kani@uwl.ac.uk*, [3]*mnasralla@psu.edu.sa*, [4]*drishty.sobnath@solent.ac.uk*, [5]*ikram.rehman@uwl.ac.uk*

[1,2,5]*www.uwl.ac.uk*, [3]*www.psu.edu.sa*, [4]*www.solent.ac.uk*

ABSTRACT

This paper presents a mobile application to assist visually impaired people (VIP) in using a university shuttle bus. The proposed mobile application utilizes technologies such as VoiceOver/TalkBack and haptic feedback to provide navigational assistance to VIP in order to partly compensate for limitations that hider their quality of life (QoL). The paper reviews the future transportation technologies that could benefit VIP by improving their QoL and enabling them to perform routine activities without any limitation.

1. INTRODUCTION

There are insignificant number of accessible mobile applications (apps) for VIP compare to the reported number of over two billion for general population (Business of Apps, 2019). The number of implemented apps based on universal design principle is insufficient to support the 2.2 billion VIP (WHO, 2019) in the world.

With the emergence of innovative technologies such as the Internet of things based sensors (Skouby, 2014), there is a vast potential in improving the QoL of VIP in terms of mobility. In recent times, several projects have successfully deployed solutions complementing the life of visually impaired by providing pervasive assistive platforms with anytime and anywhere access. Mobile assistive technologies can build the confidence of VIP in using public transportation (Golledge, 1997). Besides, features such as identifying bus stops, receiving alerts via voice or haptic regarding the estimated arrival time can significantly improve their inclination towards using the service (Sobnath, 2019). There are currently, few apps available with the similar objectives. Apps such as Lazarillo (accessible GPS) and GetThere GPS Nav provide VIP with directions to their desired locations by utilizing accessibility options embedded in the existing mobile operating systems (iOS and Android). Seeing Eys GPS and BlindSquare apps utilize GPS to provide information regarding user orientation as well as navigational instructions. However, the navigation can be inaccurate in confined spaces such as train stations and shopping malls.

There are currently some active projects running worldwide focusing on accessible services in public transportation for VIP. One of the prominent tools for VIP used in Austria (Markiewicz, 2010) requires VIP to have electronic remotes that they switch on when they hear a bus approaching when the bus is equipped with an electronic device that transmits data regarding the bus information. In Portugal, in order to enable VIP to find their directions, Lima (2018) utilized GPS and TTS by incorporating Gooble Maps API to provide navigation with voice. The iOS-based mobile application developed in Dubai translates written instructions into auditory information from the point of arrival at the metro station to the destination (RTA, 2019). GeorgiePhone was explicitly developed for VIP in UK for bus tracking, locating the nearest bus stop and the estimated time of arrival information via auditory instructions (Georgie Phone, 2015)

Within this context, in this paper MobVIP has been introduced as a tool to facilitate the accessibility of transportation services for VIP. The proposed mobile application has been explicitly designed for the visually impaired students, using the university shuttle bus in UK. Currently, there are no apps available on shuttle bus for students. MobVIP has features such as directions to the nearest bus stop and estimated bus arrival time. These information are provided to VIP via voice and haptic communication mechanisms available on the mobile device. These have been explained in more details under use cases.The main is to improve the QoL and use the application to better mobility, decrease social isolation and to empower the visually impaired students. This paper discusses the system requirements lifecycle for the proposed MobVIP application and the initial prototype designed are based on findings from the literature.

2. System Requirements

The first objective of the system was to direct the VIP user to the nearest bust stop location. For this the technological advances such as Geolocation was adapted. Some mobile service providers in UK use Network Triangulation to detect to location of mobile devices. Network Triangulation determines the Geolocation of a device by forming a triangle from known points. With the GPS technology embedded into the device, this technology has been utilised in MobVIP to identify the VIP location to the nearest bust stop.

The shuttle buses in the university are equipped with trackers and by pinging them the exact location of the bus could be identified. To calculate the distance between latitude/longitude points, the Haversine formula used to identify the nearest bus stop relative to the users' location. It was also used to estimate the bus arrival time by considering important factors such as: previous times of arrival for each stop; weather patterns; traffic and service status.

MobVIP uses the API provided by the university uTrack system that contains real-time information about the shuttle bus such as expected time of arrival. The API is enhanced from the traditional way that data is provided, and is planned to sustain models of interaction, from flat files which require a lot of work to retrieve the data and store it before carrying out a query. A query directly constructed using Representational State Transfer (REST), which inherently retrieves only the data relevant to the sent query. A similar approach is taken by uTrack. Trackers on each shuttle bus is placed by uTrack and transmits the bus geographical data to the associated API. JavaScript Object Notation (JSON) which uses normal text to send data objects consisting of array data type and attribute values, retrieves data using REST to call the uTrack API.

2.1 Use Case Diagram

The use case diagram shown in Figure 1, represents the user's interaction with MobVIP and also mobile device interaction with MobVIP. The first use case informs the user of the estimated time of arrival for the bus via voice by utilizing the device's speakers or headphones. Similarly, the second use case informs the user of the estimated time of arrival for the bus via haptic feedback. It vibrates the user's device one time for every minute that the bus will take to arrive. The third use case provides the VIP user with directions to the closest bus stop via auditory speakers to assist the user in reaching to their destination. All three use cases are triggered by the VIP, which implies that the VIP has to interact with the application for these actions to take effect.

The next three use cases are triggered by the mobile application, which implies that the user will not have to interact with the device for these actions to take effect. The first one is fetching the estimated time of bus arrival from the API. The process by calling a 'REST API GET' method from the uTrack website to fetch all the data regarding the buses. The data is then retrieved in JSON format, which is then parsed into different services, then it is mapped and placed on the app for the VIP. The second use case fetches the directions to the closest bus stop relative to the user's location. It works by sending the Google Maps API with the user's current GEO location and the location of the closest bus stop. The Google Maps API then returns the directions in JSON format. The data is then parsed and played for the user using an auditory speaker. The third use case requires the user to provide access to their GEO location even though the user does not trigger this case. After the user allows access to their location, the distance between them and all the bus stops are calculated, then the bus stops are sorted through out the app based on the closest to the user.

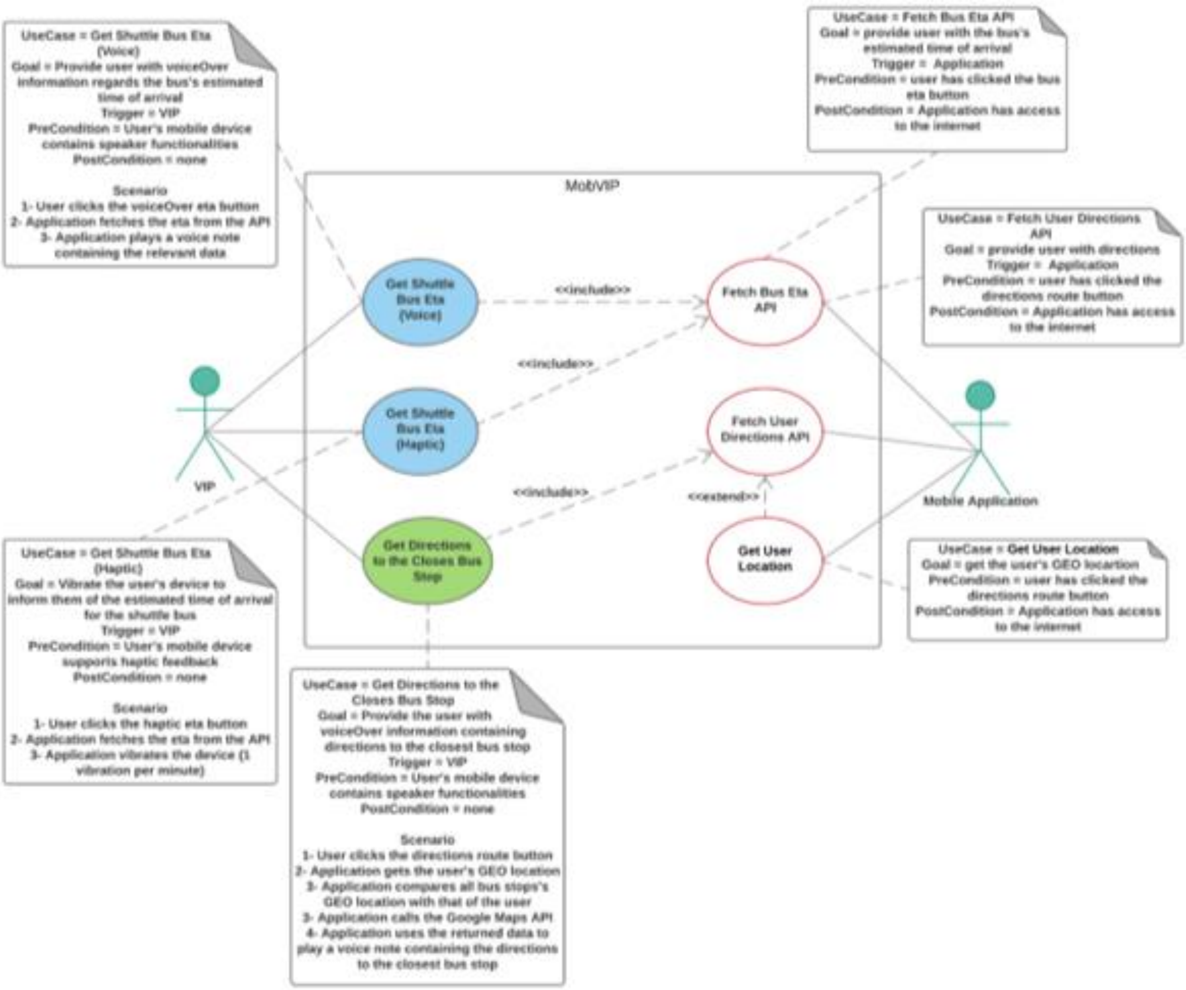


Figure 1. *MobVIP use case diagram*

3. MobVIP prototype

The mobile application was initially designed to display the university bus informationn and API for real-time data was fetched using uTrack system in JSON format. The data was parsed to be displayed in a Collection View (iOS) or List (android). The API provided data related to the bus arrival estimated time for all 6 bus stops. This was done for all future bus services and the bus GEO locations. After the data was fetched, it was placed in a singleton in order to be accessed anywhere within the application without the need of recalling the API unnecessarily. Only estimated bus arrival time provided by API and other information from Google Maps. The VIP user would receive this information via the text-to-speech built-in screen readers on Android (TalkBack) and Apple iOS (VoiceOver) devices. Hence, 3 tabs were created in the application's bottom tab bar (Figure 2).

Figure 2. *MobVIP tab bar*

The first tab is the home controller and it consists of two other tabs for each route of the bus. The information provided under Shuttle tab included: the name of the bus stop; the destination of the stop; the distance of the stop from the user; the estimated time of arrival for the bus; and the bus stop's identifying letter. The second tab is the map controller and it displays the map implemented from the Google Maps SDK. The bus stops longitude and latitude were initially retrieved manually by pin pointing the stop's location on the Google Maps website and then were plotted in the application permanently to be reused every time. The third tab consists of 5 buttons to be used by the VIP (Figure 3). It utilizes the speakers embedded in the user's device. Once the first button is clicked, an audio note is played to inform the user of the closest bus stop relevant to their location and provides the estimated time of arrival for the bus stop.

Figure 3. *VIP services.*

The second button provides the same information but via haptic feedback. This process works by vibrating the phone at an interval of 1 second for every minute that the bus will take to arrive. The third button provides audio directions to the closest bus stop, also informing the user of the duration of a journey.

4. CONCLUSIONS

The proposed mobile application is a great initiative that supports VIP with some aspects of public transportation. The requirement specification and the first prototype version of MobVIP was discussed in this paper. The next stage would be to test the application using VIP and non-VIP users. The quality of user experience needs to be observed from user's perspective and the following features would be evaluated: the directions to the nearest bus stop; estimated bus arrival time via auditory speakers/haptic feedback. The current version adheres to ubiquitous computing and is used autonomously.

5. REFERENCES

Sobnath, D, Ur Rehman, I, and Nasralla, M, (2019), Smart Cities to Improve Mobility and Quality of Life of the Visually Impaired, *Technological Trends in Improved Mobility of the Visually Impaired*. Springer. Cham. pp. 3 - 28.

WHO - World Health Organisation (2019), Accessed: October 2019. (Available at: https://www.who.int/newsroom/fact-sheets/detail/blindness-and-visual-impairment).

Golledge, R.G., Marston, J.R. and Costanzo, C.M., (1997), Attitudes of visually impaired persons toward the use of public transportation. University of California (Available at: https://escholarship.org/uc/item/5pv).

Markiewicz, M. and Skomorowski, M. (2010), Public transport information system for visually impaired and blind people. *In International Conference on Transport Systems Telematics*. Springer, Berlin, Heidelberg. pp. 271-277.

Skouby, K.E., Kivimäki, A., Haukiputo, L., Lynggaard, P. and Windekilde, I.M. (2014), Smart cities and the ageing population. In *The 32nd Meeting of WWRF*.

Georgie Phone. Last accessed June 2020. (Available at: http://www.futurepeterborough.com/project/georgie-phone/)

Lima, A., Mendes, D. and Paiva, S. (2018), Outdoor navigation systems to promote urban mobility to aid visually impaired people. *Journal of Information Systems Engineering & Management*, *3*(2), pp.14.