2024 World Congress on Virtual Rehabilitation

PRESENTED BY

ISVR & XR4REHAB

26-28 JUNE 2024

AMSTERDAM, THE NETHERLANDS

PROGRAM & ABSTRACT BOOK

ISVR
INTERNATIONAL SOCIETY FOR VIRTUAL REHABILITATION

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ORAL SESSION 1
JUNE 26, 2024

11:00 - 12:30

O1.1 Action observation with motor simulation of a virtual humanoid avatar improves reactive stepping responses in older adults with a history of falls

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O1.1

ACTION OBSERVATION WITH MOTOR SIMULATION OF A VIRTUAL HUMANOID AVATAR IMPROVES REACTIVE STEPPING RESPONSES IN OLDER ADULTS WITH A HISTORY OF FALLS

Lotte Hagedoorn[1], Ilse Leijen[1], Aurora Ruiz Rodríguez[2], Edwin van Asseldonk[2], Vivian Weerdesteyn[1 3]

[1]Radboud University Medical Center, [2]University of Twente, [3]Sint Maartenskliniek Research

Background: Reactive stepping responses are critical for preventing falls following balance perturbations. Perturbation-based training has shown to improve reactive stepping performance, but requires expensive equipment and supervision. Therefore, there is no safe and feasible way yet to perform this type of training at home. Previously, we showed that action observation with motor simulation of reactive steps (AOMS) improved reactive stepping performance in healthy young adults [1]. We aimed to investigate whether AOMS is effective to improve reactive step quality in older adults at risk of falling as well. Moreover, we investigated whether the effects differed between AOMS of a humanoid avatar or a human actor.

Methodology: Seventy older adults (68.3±5.2 years old; 52 females) with a history of at least one fall in the past year were randomly allocated to a control group (CTR) or one of the two AOMS groups (Fig1a). They were subjected to the same series of 20 balance perturbations (i.e., a forward translation of a movable platform at 3 m/s²) that elicited backward steps. The instruction was to recover balance with a single step. Before experiencing the actual perturbations themselves, the HumanAOMS participants observed and simulated a human actor's reactive steps in response to the same series of platform perturbations The AvatarAOMS group observed and simulated a virtual humanoid avatar's reactive steps instead, whose balance was perturbed by a large bird colliding from the front. The CTR group was tested without any prior AOMS. Our primary outcome was the quality of the reactive step during the 20 real balance perturbations, as quantified by the leg angle at first foot contact. We studied whether reactive step quality differed between groups across trials.

Results: Leg angles were poor (i.e. well below zero) in the first trial, without between-group differences, but improved over the course of repeated trials at different rates across groups. In the CTR group, the mean leg angles of the first nine trials were significantly lower than the grand mean of the last trial, whereas this was true for the first four trials only in the joint AOMS groups (Fig1b). The HumanAOMS and AvatarAOMS groups demonstrated similar performance (significant differences between grand mean and trials 1-3 and trials 1-4, respectively) (Fig1c).

Conclusion: Reactive step quality improved upon repeated trials in all groups, however, the AOMS groups needed fewer repetitions to reach plateau performance. Interestingly, observing and simulating reactive steps of a human actor in the same experimental context or of a humanoid avatar in a distinct virtual world yielded remarkably similar performance gains across consecutive *real* perturbations. Therefore, our findings point at the potential utility of the novel and scalable concept of AvatarAOMS in virtual reality technologies for home-based reactive balance training in older adults at risk of falling.
[1] Hagedoorn, 2024.

Keywords: Rehabilitation exergame, Action observation with motor simulation, Virtual avatar, Reactive balance, Older adults at risk of falling

O1.2

GAIT STABILITY IN VIRTUAL REALITY: THE EFFECTS OF VR DISPLAY TYPE ON HUMAN LOCOMOTION IN THE PRESENCE OF VISUAL PERTURBATIONS

J. Stephen Bergquist[1], Elizabeth B. Wilson[2], W. Geoffrey Wright[2], Daniel A. Jacobs[3]

[1]Department of Health and Rehabilitation Sciences, Temple University, [2]Department of Mechanical Engineering, University of Michigan, [3]Department of Mechanical Engineering, Temple University

Background: Virtual reality (VR) has emerged as a pivotal tool for studying balance and postural control mechanisms, leveraging unpredictable visual disturbances that dynamically challenge visuomotor processing. However, the quantity and quality of information available in the visual field may differ between VR systems, potentially introducing conflict with the intended perturbation inputs. Consequently, the extent to which the system in a VR perturbation paradigm influences its ability to elicit compensatory gait behaviors remains unclear. Here we investigate the impact of (1) VR display type, and (2) the directional axis of visual perturbations on spatiotemporal gait parameters and measures of stability.

Methodology: Sixteen unimpaired young adults were tasked with maintaining steady gait on a self-paced treadmill while viewing a VR scene presented in a rear-projection curved screen immersive room (IR) or a head-mounted display (HMD). During trials involving visual perturbations, pseudorandom oscillations were combined with forward walking velocity either in the anterior-posterior (AP), or medio-lateral (ML) direction. Metrics included averages and standard deviations (std) for spatiotemporal gait parameters (velocity, step length - SL, step time - ST), and stability indicators (step width - SW, margin of stability - MOS).

Results: When comparing unperturbed immersed walking to baseline, we found no significant main effects of visual environment on mean values for any gait metrics. However, walking in an HMD induced a significantly more variable velocity [$F(2,15) = 17.3$, $p = <0.0001$], governed by both increases in SL std [$F(2,15) = 13.5$, $p = <0.0001$] and ST std [$F(2,15) = 24.1$, $p = <0.0001$]. Main effects were also observed on stability variability measures [SW std: $F(2,15) = 4.87$, $p = 0.01$; MOS std: $F(2,15) = 3.47$, $p = 0.04$], however, differences were not significant between VR types. Regarding visual perturbations, we observed significant interaction effects between VR display type and perturbation axis on gait stability variability measures [SW std: $F(2,15) = 14.6$, $p = <0.0001$; MOS std: $F(2,15) = 29.5$, $p = <0.0001$]. Post-hoc analysis revealed significant variability increases in conditions containing ML perturbations for both VR types. Furthermore, the variability for ML perturbation trials was significantly higher when presented in the HMD [SW std, MOS std: $p < 0.0001$].

Conclusion: Our findings demonstrate that while the type of VR display does not notably alter gait metrics during unperturbed walking beyond velocity variability, it can be important during sensory conflict. The introduction of pseudorandom visual oscillations, particularly along the medio-lateral axis, significantly increases variability in stability measures. This effect is more pronounced in HMDs when compared to immersive rooms, suggesting that portable light-weight systems can provide affordable, sensitive tools for studying and training postural control and locomotion.

Acknowledgements: *The authors would like to thank Gregory Teodoro for his work in the development of the virtual reality scenes. This study was funded, in part, by the Binational Science Foundation (BSF#2019222) and the National Science Foundation (NSF#2239760).*

Keywords: virtual reality (VR), locomotion, visual perturbations, visuomotor processing

O1.3

USING A NOVEL VIRTUAL REALITY (VR) APPLICATION TO MEASURE BALANCE AND SENSORIMOTOR DEFICITS FOLLOWING MILD TRAUMATIC BRAIN INJURY (MTBI) IN VETERAN AND CIVILIAN POPULATIONS

W. Geoffrey Wright[1,2], Shirin Hussain[1,2], Madelyn Guidash[1,2], Lei Ma[1], Jingwei Wu[1], Kerri Butler[2], Rossette Biester[2], Kelly Heath[2], Randy Swanson[2], Keith Robinson[2]

[1]Department of Health and Rehabilitation Sciences, Temple University, [2]Corporal Michael J. Crescenz VA Medical Center

Background: The long-term effects of mild traumatic brain injury (mTBI) are a health concern not only for athletes involved in contacts sports, but in military service members who have increased likelihood of having a history of mTBI. MTBI symptoms often resolve within 7-10 days, but subacute signs may persist for months or years following the initial injury. For those with a military service record, there is an increased risk for concurrent psychological symptoms that are not easily dissociable from those related to mTBI. Current assessments of balance and sensorimotor function are limited by accessibility and cost, or subjectivity and poor inter-rater reliability. Here we test a novel VR technology designed to assess balance, vestibular, and visuomotor systems following mTBI, in order to help identify risk factors that may affect pre-injury functionality.

Methodology: Civilian (N=70) and veteran (n=37) were assessed using validated criterion-measures and novel VR-goggle-based measures. This included a balance assessment [(NeuroCom Sensory Organizational Test (SOT) and VR-Sensory Integration in Balance (VR-SIB)], and convergence insufficiency tests (manual Near Point Convergence-NPC, and VR-NPC). The sample included 45 individuals with and 62 without of a history of mTBI (inclusion-criterion: time-since-injury must be greater than 6 months). Correlational analysis was performed to establish criterion and construct validity, and independent means t-tests were performed to establish construct validity.

Results: The balance scores on the VR-SIB showed highly significant correlations with all comparable conditions of the criterion measure SOT (r=0.26-0.64, p< 0.01) regardless of cohort. The VR-SIB showed highly significant correlations SOT (r=0.37-0.69, p< 0.01) in those with a clinical history of mTBI. Additionally, in the healthy cohort, there were significantly higher sway scores (better balance) in various VR conditions when compared to those with a history of mTBI (t=2.29-2.50, p<0.05). There was a significant negative correlation (= -0.4060; p=0.0127) of sway area (VR-SIB Eyes Open Foam) and total number of concussions in veterans. VR-NPC test was significantly correlated with manual NPC test (r=0.39, p<0.01). The VR-NPC was correlated with manual-NPC in the healthy cohort (r=0.29, p=0.021) and in the mTBI cohort (r=0.62, p<0.001). Additionally, VR-NPC was correlated with manual-NPC when separately the civilian (r=0.32, p=0.007) and veteran (r=0.50, p<0.002) cohorts.

Conclusion: This project attempts to address a gap in current clinical balance and oculomotor assessments that are necessary for identifying possible long-lasting signs following mTBI. These results show good criterion and construct validity of novel VR-based assessments, which can provide an easy-to-use, portable, objective means for quick clinical evaluation of veterans or athletes with a history of mTBI.

Acknowledgments: The authors would like to thank Gregory Teodoro for his work in the development of the software and virtual reality scenes. This research was funded, in part, by the U.S. Congressionally Directed Medical Research Program grant (#JW200204).

Keywords: mTBI, SOT, balance, convergence insufficiency, oculomotor, vestibular

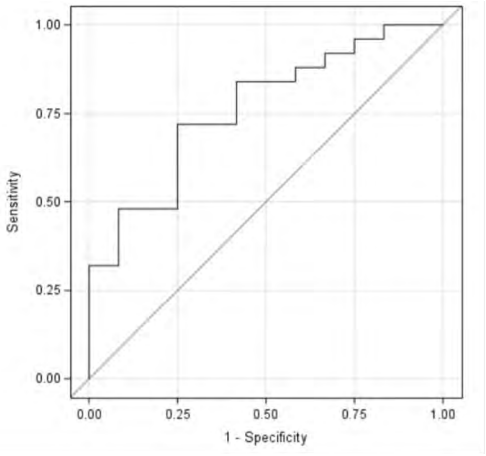

Fig 1. VR-SIB accuracy to mTBI classification. A forward, logistic regression model shows that sway area in the VR-SIB Eyes Open Foam condition is a significant predictor of mTBI history in veterans. This model has a significant ROC area under the curve of 0.763 (p=0.0015).

O1.4

GAIT-MODIFYING EFFECTS OF AUGMENTED-REALITY CUEING IN PEOPLE WITH PARKINSON'S DISEASE

Eva M. Hoogendoorn[1], Daphne J. Geerse1, A.T. van Dam[1], John F. Stins[1], Melvyn Roerdink[1]

[1]*Department of Human Movement Sciences, Vrije Universiteit Amsterdam*

Background: External cueing can improve gait in people with Parkinson's disease (PD), but there is a need for wearable, personalized and flexible cueing techniques that can exploit the power of action-relevant visual cues. Augmented Reality (AR) involving headsets or glasses represents a promising technology in those regards. This study examines the gait-modifying effects of real-world and AR cueing in people with PD.

Methodology: 21 people with PD performed walking tasks augmented with either real-world or AR cues, imposing changes in gait speed, step length, crossing step length, and step height. Two different AR headsets, differing in AR field of view (AR-FOV) size, were used to evaluate potential AR-FOV-size effects on the gait-modifying effects of AR cues as well as on the head orientation required for interacting with them.

Results: Participants modified their gait speed, step length, and crossing step length significantly to changes in both real-world and AR cues, with step lengths also being statistically equivalent to those imposed. Due to technical issues, step-height modulation could not be analyzed. AR-FOV size had no significant effect on gait modifications, although small differences in head orientation were observed when interacting with nearby objects between AR headsets.

Conclusion: People with PD can modify their gait to AR cues as effectively as to real-world cues with state-of-the-art AR headsets, for which AR-FOV size is no longer a limiting factor. Future studies are warranted to explore the merit of a library of cue modalities and individually-tailored AR cueing for facilitating gait in real-world environments.

Keywords: Parkinson's disease, Augmented Reality, Mixed Reality, gait parameters, visual cueing, HoloLens 2, Magic Leap 2

O1.5

INTEGRATING CLINICAL ASSESSMENT AND QUALITY OF MOVEMENT TRACKING INTO GAMES AND HOME: A VALIDATION STUDY

Soowan Choi[1,2], Marina Petrevska[1,3], Ilana Naiman[1], Ajmal Khan[1], Elaine Biddiss[1,2,3]

[1]*Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital,* [2]*Institute of Biomedical Engineering, University of Toronto,* [3]*Rehabilition Science Institute, University of Toronto*

Background: This study evaluated the validity of a low-cost, three-dimensional camera (Persee+, Orbbec) for movement tracking, clinical assessment, and feedback in rehabilitation and exergaming applications relative to gold standard motion capture.

Methodology: Twenty-eight participants (8 children, 20 adults) completed 14 exercises and 4 clinical assessments (i.e. 5 Time Sit-To Stand, 5TSST; Timed-Up-and-Go, TUG; One-legged Stance Test, Pediatric Reach Test) in the context of a novel exergame, *Bootle Boot Camp*, while their joint coordinate data were simultaneously collected by the Persee+ and a 12-camera, marker-based, infrared motion capture system (Motion Analysis Corp.). Metrics (e.g. trunk lateral lean <15 degrees) defining a quality repetition for each exercise were defined a priori through discussion and consensus by 7 experienced physiotherapists. The potential of the Persee+ to reliably count repetitions according to these quality metrics was described via precision, recall, and F1 scores, with ground truth established via the Motion Analysis system. For the clinical assessments, agreement between the Persee+ and the Motion Analysis system was determined via Pearson's correlation coefficient (r), root mean squared error (RMSE), Bland-Altman plots, and standard error of mean difference. Lastly, participants rated their perception of the exercise tracking on a 5 point smiley face rating scale.

Results: Three of 14 exercises (seated knee extensions, seated star jumps and sit-to-stands) had F1 scores over 90% while 6 of 18 exercises (squat, VMO Dip, hip abduction, kicking, star jumps, seated hip flexion) had F1-scores between 80 and 90%. Five exercises (static lunge, hip flexion, hip extension, lateral step and backwards step) had F1-scores between 70 and 80%. Figure 1 presents the precision-recall for each exercise. Children agreed that the game accurately tracked their exercises with an average rating of 4 (SD 0.76) out of 5. Concurrent validity was excellent for the single leg stance (r > 0.93, RMSE = 0.57s for right leg grounded and 1.52s for left leg) when the leg was raised >15 cm from the ground. Concurrent validity was excellent for the TUG (r = 0.95, RMSE=1.91s), and the 5TSST (r = 0.97, RMSE=1.08s) and good for the Pediatric Reach Test (r>0.85, *MeanDiff*:0.002-0.03m) when participants reached laterally facing the sensor to avoid occlusion of the arm.

Conclusion: Exercise counts were perceived to be reliable by participants and demonstrated good to excellent agreement with gold standard motion capture. Our results suggest that the TUG and the 5TSST can be reliably captured by the Persee+ as can the Pediatric Reach Test and the One-legged stance test with due consideration with respect to positioning of the body relative to the camera. The Persee+ sensor has high potential as a low-cost tool for monitoring exercise repetitions and for supporting clinical assessments in remote or tele-rehabilitation and exergaming applications.

Keywords: motion analysis, exergaming, telerehabilitation, validation study

O1.6

A NOVEL VR PARADIGM TO EVALUATE GAZE STABILIZATION IN VESTIBULAR REHABILITATION

Yunyi Liu[1,2], Elizabeth Dannenbaum[2], Alessia Vitullo[1,2], Thomas Ashton[2,3], Sophia Ergina[1,2], Anouk Lamontagne[1,2], Joyce Fung[1,2]

[1]McGill University, [2]Jewish Rehabilitation Hospital, [3]Dalhousie University

Introduction: Visual vertigo is provoked by visually challenging environments and is a major complaint in people with persistent postural-perceptual dizziness (3PD) who may have deficits in gaze stabilization. Clinically, the symptoms are assessed with self-reported measures such as the Visual Vertigo Analogue Scale, with a possibility of subjective recall bias. We have developed a virtual reality (VR) based paradigm to evaluate eye movements while viewing ecological scenarios with static or moving stimuli in a headset. This novel tool will be used for diagnosis and eventually interventions for 3PD.

Objectives: Evaluate the feasibility of the VR-based tool to assess eye movements and determine whether people with 3PD present altered gaze patterns compared to healthy individuals.

Methods: Participants (9 with 3PD vs. 16 healthy controls) completed the test in sitting while watching a busy subway station scene through a FOVE headset with eye movements captured. They were exposed to four different static and dynamic trials/conditions presented randomly while viewing: (1) static train station (baseline); (2) train moving from left or right; (3) static or moving train with a static balloon in the foreground; and (4) static or moving train with a balloon moving upwards. Each trial lasted 5-15s and was interspersed with a static target (white cross-hair) in between scenes, taking ~5min to complete one block of conditions. The primary measure was the total gaze trajectory path distance (GTPD) and the components of horizontal (GTPDx) and vertical (GTPDy) distances.

Results: All participants completed at least one block of testing, with most completed 3 blocks and without persistent discomfort. In the baseline (static) condition, the average GTPD was similar (p=0.484) between 3PD (27.21 ± 25.87 m) and controls (20.64 ± 19.86 m); In the condition with moving train and no balloon, the average GTPD was significantly larger (p=0.008) in 3PD (196.27 ± 229.83 m) compared to controls (82.46 ± 37.45 m). When a static target (balloon) was added to the moving train scenes, the GTPD decreased significantly in the controls (27.06 ± 32.34, p=0.006) but not 3PD (20.27± 161.65, p=0.8). The gaze changes were accounted for mainly in the horizontal movements (GTPDx) but not vertical movements (GTPDy).

Conclusion: Our new VR-based tool can feasibly assess gaze while viewing different stationary or dynamic visual environments, providing an objective assessment for 3PD. Validity of the tool is suggested by the similar gaze orientations of 3PD and control subjects in static but not dynamic environments where 3PD subjects have difficulty maintaining gaze. A static target in the foreground can be used to maintain gaze stability in dynamic environments, but 3PD subjects were less able than controls in steadying their gaze with the visual anchor. We will investigate whether vestibular rehabilitation will lead to improvements in gaze stabilization with this tool.

Keywords: Vestibular rehabilitation, Gaze, Dizziness, Visual vertigo, Virtual environment

ORAL SESSION 2
JUNE 26, 2024

14:15-15:30

O2.1 Developing and testing a new feedback-based therapy exercise game using design thinking

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O2.3 Co-design and development of a virtual reality pacing experience for long covid

O2.5 Design and evaluation of remote virtual game for cognitive Training in elderly

O2.6 Resilience tele-coaching intervention for youth with developmental disabilities and their families: description of program co-development with key stakeholders

O2.1

DEVELOPING AND TESTING A NEW FEEDBACK-BASED THERAPY EXERCISE GAME USING DESIGN THINKING

Marina Petrevska[1], F. Virginia Wright[2], Selvi Sert[2], Elaine Biddiss[2]

[1]*Rehabilitation Science Institute, University of Toronto, 2Bloorview Research Institute, University of Toronto*

Background: Children with cerebral palsy (CP) are prescribed home exercise programs (HEPs) that may account for a large portion of their therapy. HEPs are usually provided via paper-based methods which may be difficult for children and caregivers to follow and for physiotherapists to monitor (e.g., track progress, provide feedback). Movement-tracking video games have been used to make HEPs more fun, but there are few games, if any, for children that support prescription of structured exercise programs with real-time feedback to guide and reward exercise fidelity and participation. This paper explains the development and testing of a novel interactive HEP tool (i.e., Bootle Boot Camp) for children with CP that uses feedback to try to optimize movement quality.

Methodology: An iterative, multimethod development process was undertaken using design thinking. During the empathize and define stages, clinical sessions using a movement-tracking video game were observed to understand how clinicians use feedback to augment the game's therapeutic value. Home-based video games and apps were evaluated in a literature review to elucidate how feedback is delivered, and interviews were conducted to understand user needs. In ideation, game ideas were brainstormed with consideration of engagement/motivation and best practices for biofeedback in relation to motor learning (e.g., multimodal delivery and timing, fading and autonomy). During prototyping, game sketches were translated into wireframes and prototypes. Informal testing by the research team and knowledge holders was done before formal in-clinic testing with children (n=7, 5 typically developing, 2 with CP, ages 5-16 years). Children played the game and rated game features using a study-specific survey (5-point rating scales and open-ended questions). Descriptive statistics and manifest content analysis were used to analyze results.

Results: Bootle Boot Camp is an interactive exercise tool that guides children through their lower limb HEP on a television with a 3D camera-computer. It provides audio/visual cues and visual indicators (e.g., speed) based on movement execution with joint angles used to determine if repetitions are performed with high quality relative to pre-defined metrics and cues faded in line with improving performance. Movement performance and results feedback are offered concurrently during exercises, after (e.g., star ratings) and in summary form where children can review their quality markers. Children found audio feedback easier to understand (mean 4.6, SD 0.5) than visual cues (mean 3.4, SD 1.1) (Table 1), describing visual cues as repetitive and sometimes confusing. Users perceived feedback as moderately helping exercise performance (3.7, SD 1.2) and made recommendations on ways to improve delivery.

Conclusion: The iterative development process of a feedback-based therapy tool for children is described and the importance of end user involvement to optimize user acceptance.

Keywords: virtual reality; gaming; pediatric rehabilitation; home exercise programs; feedback

O2.2

BEYOND THE TRADITIONAL RESEARCH DESIGN FOR THE EVALUATION OF VIRTUAL REHABILITATION

Stephanie Jansen-Kosterink[1,2], Marian Hurmuz[1,2,] Erik Prinsen[1,3]

[1]*Roessingh Research and Development,* [2]*Biomedical Signal and Systems group, University of Twente,* [3]*Faculty of Engineering Technology, University of Twente*

Background: A proper clinical evaluation of Virtual Rehabilitation is challenging. According to the standards of evidence-based medicine, large prospective randomized controlled trials (RCTs) are considered the gold standard for evaluating the safety and effectiveness of medical interventions. Due to the rapid evolvement and complex character of Virtual Rehabilitation, the characteristics of an RCT do not match well with the clinical evaluation of Virtual Rehabilitation. It takes time to prepare and execute an RCT with sufficient power and this puts a hold on the (further) development of Virtual Rehabilitation. Among experts, it is acknowledged that there is an urgent need for alternative research designs to adequately evaluate Virtual Rehabilitation in daily clinical practice. Therefore the aim of this presentation is to list the non-traditional research designs that are currently described in scientific literature that have potential to evaluate the effectiveness and safety of Virtual Rehabilitation.

Methodology: To present the current list of these non-traditional study designs a literature search of the Medline databases was conducted in February 2024. We only included peer-reviewed papers published between 01/01/2023 and 01/01/2024 describing a clinical trial (article type) of a telerehabilitation intervention ("Telerehabilitation"[Mesh]). Potential eligibility of the papers was first identified from the titles and abstracts identified during the searches. A data extraction form was developed to systematically describe the research design used and perspective of the clinical trials.

Results: Our search led to 44 papers and 93% (n=41) of these papers met the inclusion criteria and were included in this scoping review. The three excluded papers were sub-analyses of other studies (n=2) or not performed in a clinical setting (n=1). Only in 2 papers (5%) the study design was different from an RCT. One paper described the results of a single session trial and in one paper the outcome of an observational cohort study with pre- and post-test was presented. The majority of the included papers (66%) solely addressed the clinical perspective. In 22% of the papers there was a focus on the user and clinical perspective.

Conclusion: Given the need for alternative research designs to adequately evaluate Virtual Rehabilitation in daily clinical practice the results of this scoping review are disappointing. In literature innovative research designs are described, such as the Micro-Randomized Trial, the cohort multiple Randomized Controlled Trial, the Stepped Wedge cluster randomized Trial and the single case experimental designs. All these designs are good alternatives for an RCT and are suitable to assess Virtual Rehabilitation from the end-user, clinical and societal perspective. Next to presenting our results we will take time to present our viewpoint on the in literature described innovative research designs and their advantage and disadvantage.

Keywords: Virtual rehabilitation, telerehabiliation, clinical trial, scoping review, innovative study designs

O2.3

CO-DESIGN AND DEVELOPMENT OF A VIRTUAL REALITY PACING EXPERIENCE FOR LONG COVID

Eoghan Ó Riain[1,2], David Murphy[1], Brona Fullen[3], Aaron Cole[2], Billy O'Mahony[1], Pete Moore , Ciara Hanrahan[2], Michael Twomey , Andrew Graham , Mohamad Saab , Deepak Ravindran , Cormac Ryan , Denis Martin , Joseph G McVeigh[2]

[1] *School of Computer Science & Information Technology, University College Cork,* [2]*School of Clinical Therapies, University College Cork,* [3] *School of Public Health, University College Dublin,* [4] *'The Pain Toolkit',* [5] *College of Medicine and Health, University College Cork,* [6] *Centre for Rehabilitation, Teesside University,* [7] *Catherine McAuley School of Nursing & Midwifery, University College Cork,* [8] *Royal Berkshire NHS Foundation Trust*

Background: The Covid-19 pandemic has left many patients with persistent and debilitating long-term symptoms referred to as post-acute sequelae of COVID-19, or more commonly long-covid. It is estimated that long-covid arises in approximately 10% of covid patients. People with long-covid present with a multitude of symptoms, most commonly fatigue, breathlessness and cognitive dysfunction.

Objective: To develop a home-based virtual reality (VR) intervention to assist people with long-covid to manage fatigue by developing self-management skills, in particular pacing.

Methods: The concept and story for the VR pacing intervention were designed and developed by a multidisciplinary team of researchers including: physiotherapists, doctors, nurses, occupational therapists, computer scientists, a self-management coach and a patient support organisation.
The focus of the intervention is to immerse the user in the environment without causing over-exertion. While at the same time educating the user on how best to pace, plan and prioritise everyday tasks with long-covid. This is achieved using a non-human-like character who is suffering from long-covid. The user must teach this character and by extension themselves, how to best plan and complete everyday tasks (Table 1).
It was important to keep the design user-friendly as VR is a relatively new area and not many users are experienced with the technology. Four key areas were emphasised in the design: the User Experience (UX), Scenario Integration, Energy Management and Task Reporting. To advance the design of these elements, a co-designing process with a multidisciplinary team and continuous end-user testing was adopted.

Results: A co-design process was used to collaborate and share knowledge within a multidisciplinary team.
The process incorporated usability testing with healthcare professionals, practitioners and people with long-covid. Feedback received during this testing was used to further adapt the design and update the content and its associated features. During the prototype phase of this project, 6 testing sessions were held. These sessions comprised of 2 physiotherapists, 3 occupational therapists (one of which had long-covid), 1 patient with long-covid, and 30 post-graduate physiotherapy students. The following features were added to the experience as a result of feedback from these sessions:

- A wristwatch to display the character's energy level
- Notifications to the user suggesting a short break to reduce over exertion
- Task reporting to review a user's progress over multiple sessions.

Moreover, the feedback confirmed the suitability of VR therapies for those with long-covid.
Conclusions: A co-designing process provides an effective method for the development of a VR pacing intervention application for long-covid. Co-design allows for knowledge sharing and collaboration between subject matter experts and end users.

Keywords: Virtual Reality, VR, Rehabilitation, Long Covid, Pacing, Physiotherapy, Co-design, User Experience, UX.

O2.5

DESIGN AND EVALUATION OF REMOTE VIRTUAL GAME FOR COGNITIVE TRAINING IN ELDERLY

Iveta Fajnerová[1], Marketa Zakurdajeva[1], Vaclav Sahula[1]

[1]*National Institute of Mental Health*

Background: Due to demographic aging, cognitive decline in the elderly presents a pressing issue. It was suggested that virtual reality (VR) can easily simulate activities of daily living (ADLs) and train everyday skills in a safe environment [1,2], thus increasing ecological validity of serious games. Our study aims to evaluate the feasibility of a remote cognitive training game with VR features for elderly utilizing a combination of traditional drill-practice and the strategy-based approach.

Methodology: The training game TREKOG consists of two mutually independent environments: a desktop application installed on a personal computer (built in Unity) and a dynamic website that provides the basic interface for user accounts. Both environments are connected by the database repository. The training game includes a basic game module for daily routines where the user interacts with the environment and meets the neighbors living in nearby apartments. In addition to the daily routine, the app includes a set of mini-games built on a custom modular system. All data and results of the user's actions are fed back into a database repository and later accessed from the web. The game is designed for a minimum of 20 training sessions.

Results: The TREKOG game was tested in a feasibility study in 35 elderly respondents aged 60-78 (mean age 65, 19 females). The respondents gave us feedback using an online questionnaire (forms.nudz.cz). Among the respondents, the vast majority (N=30) were retired or partially employed while receiving retirement pension. The overall feedback was very positive across respondents. Seniors perceived the game as intuitive, fun and reasonably challenging. The behavioral game results will be presented in more detail during the conference.

Conclusion: The study demonstrated the TREKOG game as feasible in elderly population. The obtained feedback will be used to modify the game accordingly for a future study comparing the pre/post effects of remote TREKOG training with a VR-based cognitive training in an attendance form.

Acknowledgement: The Trekog game was created in the project PoC of commercialisation concepts formulated by ILA II CZ.07.1.02/0.0/0.0/16_040/0000369 and later tested in the project Research of Excellence on Digital Technologies and Wellbeing CZ.02.01.01/00/22_008/0004583 co-financed by the European Union.

Keywords: Cognitive Training; Serious games; Elderly; Remote access; Virtual reality;

O2.6

RESILIENCE TELE-COACHING INTERVENTION FOR YOUTH WITH DEVELOPMENTAL DISABILITIES AND THEIR FAMILIES: DESCRIPTION OF PROGRAM CO-DEVELOPMENT WITH KEY STAKEHOLDERS

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Background: Children with neurodevelopmental disabilities (NDDs, e.g., cerebral palsy) and their caregivers face lifelong and impactful challenges, particularly during life-transition periods such as adolescence. Resilience, defined as the ability to overcome challenges, emerges as essential in navigating this vulnerable phase. We previously identified important gaps and limitations in interventions that address resilience for this population, highlighting the need for innovative solutions. The objective is to describe the co-development process of a resilience tele-coaching intervention for youth with NDDs and their families and outline the role of the key stakeholders in this process.

Methods: The proposal is embedded in an integrative knowledge translation (iKT) approach, where the engagement of key stakeholders (n=3) is central to the co-design of the program. A robust process was applied to support the initiative, the Knowledge to Action framework: *Step 1 – Create knowledge and Step 2 – Adapt to local context*. In Step 1, a scoping review approach using the Arksey & O'Malley framework, including stakeholder consultation, was undertaken to identify relevant resilience factors. In Step 2, we launched a national survey to caregivers and young adults with NDD, exploring their preferences regarding online coaching and validating content.

Results: Step 1 study screened 1,191 publications, selecting fifty-eight studies. Findings revealed that resilience in this context is closely linked to more than forty factors across four levels (individual, family, school/peers, community). Pivotal factors include social and emotional competence, optimism, and relationships. Stakeholders highlighted the importance of addressing caregivers' self-efficacy and self-esteem, as well as youth's and caregiver's confidence. Preferences for and advantages of online delivery for support programs and individual/group features also emerged. Currently, Step 2 study is underway (i.e., survey is launched), with preliminary content for the program designed. It features five self-guided online learning modules for caregivers and five for youth, targeting the most significant resilience factors identified in Step 1. Modules include educational material and curated activities to optimize learning and enhance user engagement. Caregiver and youth partners are actively reviewing these, providing feedback, and sharing their stories and experiences, which will be incorporated into the material. The survey results will serve as valuable insights to enhance and refine the program further.

Conclusion: The co-development of a resilience tele-coaching intervention for youth with NDDs and their families, guided by an iKT approach, has progressed through rigorous steps involving key stakeholders. Insights from this process will contribute to refining and optimizing the program for the unique needs of youth with NDDs and their families during crucial life-transition periods.

Keywords: resilience, online coaching, youth, developmental disabilities, integrated knowledge translation

ORAL SESSION 3
JUNE 27, 2024

14:15-15:45

O3.1 Effects of physical inactivity on circumvention strategies in older adults: preliminary results

O3.2 Whack away: leveraging vr's potential to unveil neglect - lessons learned about patients' and clinicians' needs

O3.3 Effectiveness of dual therapy of combination of brain-computer Interface, virtual reality and functional electrical stimulator on Motor skills recovery in stroke patients of varied severity: a case Study

O3.4 Remotely prescribed, monitored and tailored home-based gaitand- Balance exergaming intervention using augmented-reality glasses: a clinical feasibility study in people with Parkinson's Disease

O3.5 Stroke patient-specific MU event-related desynchronization during Motor imagery and observation in a VR-based BCI intervention

O3.6 Preliminary evidence of functional and cortical changes after upper limb rehabilitation using a virtual reality-based tabletop System

O3.1

EFFECTS OF PHYSICAL INACTIVITY ON CIRCUMVENTION STRATEGIES IN OLDER ADULTS: PRELIMINARY RESULTS

Joris Boulo[1], Margaux Simon[1], Bradford J. McFadyen[1], Andréanne K. Blanchette[1]

[1]*School of Rehabilitation Sciences, Université Laval*

Background: Moving safely and autonomously around a community-based, public environment requires avoiding fixed and moving obstacles [1]. Physical inactivity due to a sedentary lifestyles have been linked to a notable decrease in muscular abilities [2,3], compromised proprioception [4], and overall reduced social interactions [5]. According to the World Health Organization, 31.3% of persons aged 15 and older do not meet the recommendations for physical activity. In recent work (unpublished), looking at the effect on physical inactivity on circumvention strategies in young adults, results showed that physical inactivity induced a more cautious behaviour. Given the aging population, it will be important to understand the combined effects of age and inactivity.
The objective of this study was to better understand the influence of physical activity level on anticipatory locomotor adjustment strategies, related muscles activations and visual attention during a pedestrian circumvention task in healthy adults over 65 years old.

Methodology: Two groups of 15 older adults (15 active and 15 inactive distinguished by the Questionnaire for older adults on physical activity, will be recruited. The participants' task is to read a simple word on a sign in a virtual park (LogVS [6]) programmed with UnReal (V5.2) presented in a virtual reality headset (Meta Quest Pro, 90 Hz, wireless) (Figure 1). Participants walked straight ahead unobstructed (control condition) or circumvented the virtual pedestrian walking straight toward them (studied condition). Catch trials included the pedestrian turning right or left.

Electromyographic activity (both Tibialis anterior and Medial Gastrocnemius; Delsys Inc.; 2000 Hz) and kinematics (Vicon, HMD) of the participants are recorded, respectively. These data are used to calculate trajectory deviation distances from the virtual pedestrian, minimal clearance, visual attention given to the VE as well as the co-activation of antagonist ankle muscles. Non-parametric statistical analyses of longitudinal data (NparLD) are used.

Figure 1: View of part of the VE park interior as seen by the user at the starting point.

Results: The preliminary results (n= 10 active participants (4 females) and 5 inactive participants (5 females)) show that participants with an inactive lifestyle deviated farther (4.83m ± 1.16) from the virtual pedestrian compared to active participants (2.85m ± 0.73) (p= 0.005). However, both groups maintained a similar clearance (p= 0.482) and a similar walking speed during the pedestrian circumvention (p= 0.327).

Conclusion: These preliminary findings already suggest that, like for young adults, an inactive lifestyle may influence circumvention strategies with adding to cautious locomotor navigational behaviour in a social community context already found for older adults [7]. This highlights the importance of promoting physical activity for safer mobility in older adults. The results will be further confirmed with the addition of more participants in each group.

Aknowledgment: We would like to thank team members Sylvain Comtois, PEng, and Félix Fiset, Mpt, MSc for their continued assistance. This project was funded by Natural Sciences and Engineering Research Council of Canada (RGPIN/191782-2023; BJM) and the Réseau provincial de recherche en adaptation-réadaptation (REPAR; 0101674). JB received a bursary from the Centre interdisciplinaire de recherche en réadaptation et intégration sociale (Cirris).

O3.2

WHACK AWAY: LEVERAGING VR'S POTENTIAL TO UNVEIL NEGLECT - LESSONS LEARNED ABOUT PATIENTS' AND CLINICIANS' NEEDS

Bastian Ilsø Hougaard[1], Iris Brunner[2], Lars Evald[2], Hendrik Knoche[1]

[1]*Aalborg University,* [2]*Hammel Neurorehabilitation Centre and University Research Clinic, University of Aarhus*

Background: Virtual reality-assisted neurorehabilitation is becoming increasingly popular as the need for rehabilitation services increases due to the ageing population worldwide.
Rehabilitation systems are undergoing transformation with the availability of affordable VR technology, capable of facilitating and quantifying continuous and intensive exercise. Designers of digital therapeutic applications can leverage VR capabilities to provide clinicians with novel insights for treatment and diagnosis of common stroke-related conditions, such as unilateral spatial neglect.

Methodology: In a comprehensive five-year interdisciplinary collaboration, we developed a therapeutic application called 'Whack-A-Mole' designed to diagnose and treat unilateral spatial neglect through an upper-limb pointing exercise. The application features tracking of head, eyes and hands while being adjustable to individual needs. This application enables clinicians to create specialized treatment programs incorporating virtual controller offset, prism adaptation, mirror therapy, and visual manipulation of the virtual environment. A clinician dashboard was developed for data visualization and summary at the end of exercises. The design process drew insights from preliminary studies of passive viewing tasks and numerous usability tests in VR with patients and clinicians.

Results: Our collaboration yielded insights for digital rehabilitation systems, specifically system requirements to support patients', clinicians', and researchers' needs. Some patients with stroke experienced challenges when interacting with VR, due to e.g., reduced communication ability, the need for continuous body posture corrections, or mental and physical fatigue. Clinician challenges concerned the need to simultaneously monitor screens and patients, and to have a solid foundation to analyze events within the virtual environment. Research challenges required labor-intensive adaptations to suit clinical reality were necessary. Moreover, temporal gaps between data collection and subsequent data analysis and visualization prolonged the process.

Conclusion: While commercial VR technology holds promise in rehabilitation, our findings highlight risks that need to be addressed in digital therapeutic application development. Building on insights from our collaboration, our 'Whack-A-Mole' system is now undergoing preparation for a case-control study, to test treatment programs with both stroke patients and healthy controls. For the longer term we wonder how to address the medical device regulation for scaling up.

Keywords: VR, virtual reality immersion therapy, hemispatial neglect, unilateral spatial neglect, diagnostic techniques and procedures, eye tracking, head rotation, stroke, acquired brain injury

O3.3

EFFECTIVENESS OF DUAL THERAPY OF COMBINATION OF BRAIN-COMPUTER INTERFACE, VIRTUAL REALITY AND FUNCTIONAL ELECTRICAL STIMULATOR ON MOTOR SKILLS RECOVERY IN STROKE PATIENTS OF VARIED SEVERITY: A CASE STUDY

Francisco Fernandes[1], Ünal Hayta[1], Woosang Cho[1], Sebastian Sieghartsleitner[1], Marc Sebastián-Romagosa[2], Rupert Ortner[2], Christoph Guger[1,2]

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Background: Combining Brain-Computer Interface (BCI), Functional Electrical Stimulation (FES), and Virtual Reality (VR) significantly enhances stroke rehabilitation, as demonstrated in our case study that tracks patients across two therapy sessions. This innovative approach yields considerable improvements in motor skills, emphasizing the importance of personalized, ongoing therapy for optimal outcomes. Our research shows that patients with varying degrees of stroke severity benefit significantly from this multimodal method, highlighting its adaptability and effectiveness in diverse recovery scenarios. Continuous, tailored therapy is critical to maximizing the benefits of BCI, FES, and VR in stroke recovery.

Methodology: Three stroke patients with three severity levels were recruited to participate in this study, each undergoing a total of 50 therapy sessions, comprising two phases of 25 sessions each. Assessments were conducted at three distinct time points: before the initiation of therapy, following the completion of the first 25 sessions, and upon the conclusion of all 50 sessions. These assessments were implemented to track changes in motor abilities throughout rehabilitation systematically.

Results: After therapies, improvements in motor skills were monitored by three assessment scores: Upper Extremity Fugl-Meyer (UE-FMA), 9-hole Peg Test (9HPT), and Box and Block Test (BBT). Case 1, with moderate impairment, improved in 9HPT from 155s to 64s (25 sessions) to 56.5s (50 sessions) and in BBT from 21 to 39 blocks (25 sessions) to 44 blocks (50 sessions). Case 2, mildly impaired, enhanced 9HPT from 144.7s to 75.3s (25 sessions) to 39.5s (50 sessions) and BBT from 23 to 29 blocks (25 sessions) to 45 blocks (50 sessions). Case 3, severely impaired, showed UE-FMA improvement from 29 to 30 (25 sessions) to 45 (50 sessions), unable to perform 9HPT and BBT.

Conclusion: The study demonstrates that integrating BCI, FES, and VR technologies significantly enhances motor skill rehabilitation in stroke patients of varying severity, emphasizing the critical role of personalized, continuous dual therapies in achieving optimal recovery outcomes.

Keywords: Brain-Computer Interfaces, Virtual Reality, Functional Electrical Stimulator, Stroke, Neurorehabilitation

O3.4

REMOTELY PRESCRIBED, MONITORED AND TAILORED HOME-BASED GAIT-AND-BALANCE EXERGAMING INTERVENTION USING AUGMENTED-REALITY GLASSES: A CLINICAL FEASIBILITY STUDY IN PEOPLE WITH PARKINSON'S DISEASE

Lotte E.S. Hardeman[1], Daphne J. Geerse[1], Eva M. Hoogendoorn[1], Jorik Nonnekes[2,3], Melvyn Roerdink[1]

[1] *Department of Human Movement Sciences, Vrije Universiteit Amsterdam,* [2] *Department of Rehabilitation, Radboud University Medical Centre,* [3] *Department of Rehabilitation, Sint Maartenskliniek*

Background: Despite increasing recognition of the importance of exercise in the management of Parkinson's disease, adherence to exercise remains challenging. Exergaming (i.e., a combination of exercise and gaming) has the potential to increase adherence to exercise through play, individually tailored training and (online) remote monitoring. Reality DTx® is a digital therapeutic software platform for augmented-reality glasses (AR) that enables a home-based gait-and-balance exergaming intervention specifically designed for people with Parkinson's disease (pwPD). The primary objective was to evaluate the feasibility and potential efficacy of Reality DTx® AR-exergaming intervention for improving gait, balance and walking-adaptability fall-risk indicators. The secondary objective was to evaluate potential AR-glasses superiority (Magic Leap 2 [ML2] vs. HoloLens 2 [HL2]).

Methods: This waitlist-controlled clinical feasibility study comprised three laboratory visits (baseline; pre-intervention; post-intervention), a home visit and a 6-week AR-exergaming intervention. Five complementary gait-and-balance exergames (see Figure 1) were remotely prescribed (default five sessions/week of 30 active minutes/session), monitored through an online web portal and tailored following FITT principles (frequency, intensity, type and time). All important aspects for delivering a progressive-but-achievable intervention. Feasibility was assessed in terms of safety, adherence and user experience. During laboratory visits, gait-and-balance capacity was assessed using standard clinical gait-and-balance tests and advanced walking-adaptability fall-risk assessments.

Results: 24 pwPD participated. No falls and four near falls were reported. Session adherence was 104%. Reality DTx® reached above average scores for User Experience Questionnaire subscales Efficiency and Dependability, good scores for Perspicuity and Novelty and excellent scores for Attractiveness and Stimulation, with superior scores for HL2 over ML2 for Perspicuity and Dependability. Intervention effects were observed for the Timed-Up-and-Go test (albeit small), the Five-Times-Sit-to-Stand test and walking speed. Walking-adaptability fall-risk indicators all improved post-intervention.

Conclusion: Reality DTx® is safe, adherable, progressive-but-achievable, well-accepted and potentially effective for improving gait, balance and walking adaptability in pwPD. These promising results warrant future RCTs on the (cost-)effectiveness of home-based AR exergaming interventions for improving gait, balance and fall risk.

Keywords: Parkinson's disease, augmented-reality, gait, balance, walking adaptability, exergaming, digital therapeutics

Trial registration: ClinicalTrials.gov, NCT05605249, Registered 4 November 2022, https://clinicaltrials.gov/ct2/show/NCT05605249

Preprint: 10.21203/rs.3.rs-3035368/v1

O3.5

STROKE PATIENT-SPECIFIC MU EVENT-RELATED DESYNCHRONIZATION DURING MOTOR IMAGERY AND OBSERVATION IN A VR-BASED BCI INTERVENTION

Madalena Valente[1], Diego Blanco-Mora2, Jean-Claude Fernandes[3], Sergi Bermúdez i Badia[2], Patrícia Figueiredo[1], Athanasios Vourvopoulos[1]

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Background: Restorative Brain-Computer Interfaces (BCIs) offer a promising avenue for stroke patients with impaired voluntary movement, by providing a non-muscular communication pathway. BCIs facilitate the modulation of sensorimotor rhythms (SMR) measured using Electroencephalography (EEG) during motor-imagery (MI) and motor observation (MO) through the integration of embodied proprioceptive feedback, which may be delivered via immersive virtual reality (VR). To date, there is increasing evidence that SMR-based BCIs could promote long-lasting improvements in motor function in chronic stroke patients. Nonetheless, not many studies take into account the patient-specific features of post-stroke SMR patterns. Instead, SMR is usually assessed as the event-related desynchronization (ERD) of the Mu band using the fixed frequency band limits of 8-12 Hz. Taking into account the known between-subject variability in EEG measurements, and the individualized clinical profile of each stroke patient (e.g. lesion size, location), it is important to investigate the impact it could have on the generation of the SMR. With this in mind, we present a method where the individual frequency band of the ERD is extracted from each patient (iERD), and compared to the standard ERD range.

Methodology: Four chronic stroke patients underwent a 3-week (12 sessions) longitudinal intervention involving MI and MO practice of the right and left hand through the use of a VR-based EEG-BCI system. EEG was recorded from 32 channel locations across all sessions. The data was pre-processed, to remove artifacts and noise. Next, the ERD was computed as the relative drop of power during MI/MO, between (a) the standard fixed mu bandwidth of 8-12 Hz (standard ERD), and the (b) individual mu band modulation (iERD), by detecting a custom bandwidth where the power drop is greatest. A t-test statistical test was used to quantify whether the difference between the two methods is statistically significant from the central electrodes (C3 or C4) over the ipsi- and contra-lesional sensorimotor areas.

Results: By comparing the standard ERD with iERD, we found significant differences for all patients in both ipsi- and contra-lesional electrodes (Figure 1), with iERD revealing significantly increased desynchronization (more negative) than fixed ERD. Moreover, with the computation of topographical maps, we observe more clearly and focally the spatial distribution of the iERD compared to ERD over the lesioned side of each patient.

Conclusion: Our results suggest that focusing on the individual mu band to obtain a patient-specific ERD allows us to extract features that more accurately explain individual SMR modulation and account for the between-subject variability. Taking into account that the induced ERD can be impacted by the stroke lesion, iERD offers a better and more targeted detection of the evolution of the SMR during MI/MO-BCI training, augmenting the rehabilitation outcome.

Keywords: Brain-Computer Interfaces; Electroencephalography; Event-related desynchronization; Motor Imagery; Neurorehabilitation

O3.6

PRELIMINARY EVIDENCE OF FUNCTIONAL AND CORTICAL CHANGES AFTER UPPER LIMB REHABILITATION USING A VIRTUAL REALITY-BASED TABLETOP SYSTEM

Ana Sierra[1], Anny Maza[1], Sandra Goizueta[1], María Dolores Navarro[2], Carolina Colomer[2], Enrique Noé[2], Roberto Llorens[1]

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Background: Hemiparesis is one of the most common and disabling impairments after stroke. Neuroimaging studies using functional magnetic resonance imaging or functional near-infrared spectroscopy (fNIRS) have shown that individuals with hemiparesis post-stroke may exhibit increased cortical activity in homologous regions of the unaffected hemisphere (i.e. decreased activity in the affected hemisphere) when moving the hemiparetic extremity. The bilateral increase of neural activity tends to resolve over time into lateralized activity patterns, which is associated to functional improvement.

An increasing number of studies report benefits in the upper limb motor function from interacting with virtual reality (VR)-based systems that provide engaging, motivating, challenging and task-oriented exercises. Functional improvements after interacting with these systems have been also associated with cortical changes. We have developed a VR-based tabletop system that provides audiovisual and haptic feedback and enables interaction through a 42-inch multitouch screen. The system features a cooking game that requires performing different hand and arm movements to complete a series of recipes. The aim of this study was to investigate the functional and cortical changes of a sample of individuals post-stroke after an intervention with the system.

Methodology: Four subjects (50% women), with a median age of 52.5 (IQR=34.7-73.2) years and a time post-injury of 13.9 (IQR=7.6,14) months, without severe cognitive deficits, and with active proximal and distal movements participated in this study.
The intervention consisted of 20 sessions of 20 minutes of conventional physical therapy plus 20 minutes of interaction with the VR system. The upper limb function of the participants was assessed with the Fugl-Meyer Assessment for upper extremity (FMA-UE) and the Box and Blocks test (BBT) before and after the intervention. The neural activity in both hemispheres was investigated at the same time points through fNIRS while opening and closing the hemiparetic hand.

Results: All patients improved their motor function after the intervention (Figure 1). Motor improvement was accompanied with lateralization of the brain activity towards the affected hemisphere in all patients but in the one who had the least motor improvement.
Conclusion: These preliminary findings suggest that the combined training of upper limb through conventional and gamified multitouch VR-based training can promote motor and neural recovery post-stroke.

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Keywords: virtual reality, multitouch, tabletop, upper limb, stroke

ORAL SESSION 4
JUNE 28, 2024

09:00 - 10:30

O4.1 Towards physiological detection of a “just-right” challenge level for motor learning in immersive virtual reality: preliminary results in typically developing children and children with hemiplegia

O4.2 Validation of a VR-based driving simulator for powered wheelchairs in children with cerebral palsy

O4.3 Validation of a simulated museum VR application for disability awareness

O4.4 Mixed reality patient education during spinal cord injury rehabilitation: an evaluation study of feasibility and learning effects

O4.5 Feasibility of VR to promote health literacy in primary care from the health professionals view: a multi-national qualitative study

O4.6 Incorporating extended reality into brain injury rehabilitation: insights and challenges for patient-therapist communication during therapy

O4.1

TOWARDS PHYSIOLOGICAL DETECTION OF A "JUST-RIGHT" CHALLENGE LEVEL FOR MOTOR LEARNING IN IMMERSIVE VIRTUAL REALITY: PRELIMINARY RESULTS IN TYPICALLY DEVELOPING CHILDREN AND CHILDREN WITH HEMIPLEGIA

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Background: Motor learning in rehabilitation is facilitated when tasks are presented at a 'just-right' challenge level: at the edge of the child's current abilities, yet attainable enough to motivate the child in persistent efforts to succeed. Immersive virtual reality (VR) may be ideally suited for 'just-right' task challenge because it enables precise adjustments of task parameters in motivating environments. Objective physiological measurement of cognitive processes (e.g. engagement) using wearable sensors could facilitate 'just-right' challenge detection. The objective of this study is to explore the relationships between physiological data and self-reported cognitive state at different task difficulty levels of a novel immersive VR task.

Methodology: Cross-sectional, within-participant study. Children with hemiplegia and typically developing children aged between 6-16 years old participated in a 60-minute data collection session during which they played a seated unimanual immersive VR task (bouncing a ball with a paddle). A 12-lead electroencephalography (EEG) unit (Kaptics) was integrated within a Pico Neo 4 head mounted display. After resting data collection, children completed a 1-minute game play introduction trial, a 3-minute trial at medium task difficulty (performance informed starting difficulty level for subsequent trials); and three, 3-minute trials at individualized progressive difficulty levels. Following each session, participants answered a 7-point Likert-scale questionnaire with anchors on 'not at all true' and 'completely true' asking their agreement with statements on level of engagement and cognitive workload. Descriptive statistics synthesized demographic data; Mann-Whitney U tests evaluate relationships between self- reported cognitive processes and EEG indexes of engagement and focus. Participants were categorized as reporting low or high engagement or cognitive workload based on questionnaire responses.

Results: 7 children participated (5 typically developing; M=8.8 yo, SD=1.3; 2 with hemiplegia, M=9 yo, SD=4.2). Mann-Whitney tests indicate significant differences (p=.020, Z=-2.313) between the low and high engagement groups in terms of EEG engagement index (M-low=48.57 SD-low=26.85; M-high=72.91, SD-high=8.5). No significant differences (p=.073, Z=-1.796) were found between the low and high cognitive load groups in terms of EEG focus index (M-low=81.05 SD-low=11.13; M-high=68.75, SD- high=8.18).

Conclusion: Preliminary results indicate that EEG engagement metric could be a non-intrusive option for engagement measurement, allowing researchers to avoid interrupting children's immersive VR experience for self-report questions. This variable seems to align better with children's expressed experience. Ongoing data collection will provide a larger sample size to support more conclusive recommendations. Repeated measures correlations will allow deeper exploration of relationships.

Keywords: Immersive Virtual Reality; Pediatric rehabilitation; BCI; Engagement

O4.2

VALIDATION OF A VR-BASED DRIVING SIMULATOR FOR POWERED WHEELCHAIRS IN CHILDREN WITH CEREBRAL PALSY

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Background: Cerebral Palsy (CP) is the primary cause of childhood neuromotor disability, often leading to the necessity of powered wheelchairs (PW) due to limited motor control. Adequate training is crucial for mastering PW maneuvering. Despite the Powered Mobility Program (PMP) assessing driving skills, objective proficiency measures are scarce [1]. As such, we developed VR-PMP, a virtual reality (VR) driving simulator to investigate if VR-based simulators can enhance training and assessment of driving skills [2].

Methodology: The VR-PMP can connect to a VR headset (immersive mode) or be used with a laptop and monitor (semi- immersive mode). The system can be controlled through the VR headset joysticks or alternative access technologies (Figure 1). It encompasses 20 tasks outlined in the PMP and generates scenarios simulating driving in realistic environments, providing overall scores based on collision count, trajectory execution, and time taken per level. Five children and adolescents with CP, aged 9 to 20, participated in the study and underwent 3 outpatient and 9 home training sessions using the VR-PMP. Participants wore a wearable wristband (Empatica E4), capturing physiological signals (photoplethysmography, PPG; acceleration; skin temperature; electrodermal activity, EDA) to analyze potential VR side effects. A preliminary session assessed VR headset tolerance and included a road driving test using the PMP to evaluate driving skills. The 3 outpatient sessions included a PMP evaluation assessed by one therapist while participants used the simulator. These sessions were interspersed with 2 cycles of home sessions during which participants practiced independently with the simulator. The last outpatient session included a repetition of the PMP road test. Lastly, questionnaires assessing motion sickness (Motion Sickness Assessment Questionnaire, MSAQ), mental and physical effort (NASA Task Load Index, NASA-TLX), simulator usability (Game-Design Questionnaire, GDQ), and sense of presence (Igroup Presence Questionnaire, IPQ) to gauge immersion and engagement during the VR experiments were administered during the intervention.

Results: Four of the 5 participants completed the sessions, but their prior familiarity with VR influenced the simulator usage. Higher fatigue emerged during the road test compared to simulator sessions, and physiological signals indicated increased sympathetic activity during VR use (Figure 1). Finally, participants reported feeling relaxed during the trials. To further evaluate the agreement between the PMP overall score and the VR-PMP simulator score for assessing wheelchair driving abilities, a Bland-Altman analysis was performed, yielding a mean percentage error of 2.97%.

Conclusions: The VR-PMP has the potential to enhance PW driving training for children with CP, offering objective measures to aid rehabilitation experts in assessing driving performance and fostering greater levels of independence.

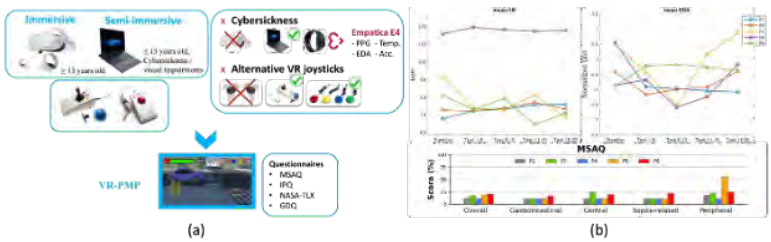

Figure 1. (a) VR-PMP intervention for immersive and semi-immersive modes; Empatica E4, a wearable device for cybersickness evaluation based on photoplethysmography (PPG) acceleration (acc), skin temperature (temp), electrodermal activity (EDA); alternative access technologies for VR-PMP. (b) Mean heart rate (HR) estimation from PPG, mean EDA, and MSAQ scores over the 20 tasks during the first VR-PMP session.

O4.3

VALIDATION OF A SIMULATED MUSEUM VR APPLICATION FOR DISABILITY AWARENESS

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Introduction: People with disabilities encounter barriers to their participation in their daily activities. Some of these barriers are due to the social environment, i.e., attitudes and behaviour of other individuals with respect to persons with disabilities. There is a need to raise awareness about disability, in particular in employees of public and private establishments, who may encounter people with disabilities. It has been shown that role playing activities and discussions can be effective in raising awareness about the challenges experienced by people with disabilities. As such, virtual reality (VR) can be an effective tool for disability awareness. Therefore, two VR scenarios were developed through a co-design approach, involving individuals with disabilities and museum employees with expertise in accessibility. These scenarios explore social and physical barriers that a person with either a motor or visual impairment may experience while visiting a museum. The specific aim of this study was to evaluate the validity of our VR, disability awareness scenarios in terms of realism, potential usefulness and ease of use.

Methods: Five persons with disabilities (two with a visual impairment and three with a motor impairment) and seven museum employees were recruited for the study. Two VR scenarios were tested by the participants: a museum visitor with either a mobility impairment (wheelchair user) or a visual impairment, using the Oculus Quest 2 VR Headset. Following this, a semi-structured interview was conducted to gather information about the degree of realism, potential usefulness and overall ease of use of the VR disability awareness tool. Examples of questions included: "What characteristics in the virtual environment struck you?" and "How realistic do you think the tasks and activities of these scenarios are?" Interviews were recorded and transcribed verbatim, and then coded through a qualitative content analysis.

Results: Four main themes were identified. The first was 'Emotions', which included both negative (frustration, confusion) and positive (empathy) emotions experienced by participants in the VR scenarios. The second theme was 'Experience', or how the VR scenarios matched the participants' lived or professional experience. The third theme, 'Usefulness', described how the VR scenarios could be used as an 'icebreaker', to then teach appropriate interactions with persons with disabilities, and to increase awareness. In the fourth theme, 'Realism', participants explained how the VR scenarios presented a realistic rendition of accessibility/inaccessibility and of interactions with museum employees.

Conclusion: Our scenarios were seen as useful in describing social and physical barriers experienced by persons with disabilities. VR can be a valid tool to promote disability awareness among employees in a sociocultural setting to improve the inclusion of people with disabilities.

O4.4

MIXED REALITY PATIENT EDUCATION DURING SPINAL CORD INJURY REHABILITATION: AN EVALUATION STUDY OF FEASIBILITY AND LEARNING EFFECTS

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Background: The neurological consequences of spinal cord injury (SCI) are complex and patients require effective education about SCI and secondary conditions such as neurogenic bladder and bowel dysfunction to improve their self-management and long-term health. However, conventional education methods have barriers [1]. A recent review showed Mixed Reality (MR) to be a suitable technology to strengthen knowledge transfer in patient education in other diseases, because of the use of interactive three-dimensional human-like visuals (holograms), the provision of information using different modalities (and thus reducing cognitive overload), and increased motivation for learning [2]. We developed an MR patient education specifically for SCI, explaining the basic neurological consequences and detailed modules about neurogenic bladder and bowel dysfunction and management. This study addresses feasibility and learning effects in an inpatient SCI population.

Methodology: We assessed feasibility and learning effects by questionnaires and semi-structured interviews in persons with recently diagnosed SCI in an inpatient rehabilitation setting. For feasibility, we used three outcome measures with a priori set thresholds: the System Usability Scale (SUS) to measure usability (threshold >68, meaning above average), a numerical rating scale (NRS) range 0-10 for user-satisfaction (threshold >7), and the Intrinsic Motivation Inventory (IMI, range 7-49, higher scores reflect higher motivation, threshold >35) for motivation. We tested learning effects by statements about subjective SCI knowledge (possible range 0-88, higher scores reflect higher subjective knowledge), and NRS (range 0-10) satisfaction with SCI knowledge, comparing scores before and after the use of the MR modules.

Results: Quantitative analysis of the first 7 participants showed positive usability (SUS median 72.5, range 33-98), user-satisfaction (median 8, range 5-9), and intrinsic motivation (median 42, range 22-49), confirming feasibility. Agreement with statements on subjective knowledge (median 46 before, 69 after), satisfaction with general SCI knowledge (median NRS 6 before, 8 after) and satisfaction with bladder knowledge (median NRS 5 before, 8 after) increased significantly. Interviews with the first 3 participants were analysed. They mentioned several advantages of MR, for example visualisation, better sustained attention and multimodal input. Their overall experience was satisfactory, and they also provided suggestions to improve usability and implementation in daily practice.

Conclusion: MR patient education proved feasible and has positive effects on learning in this study, therefore it might be a promising tool to enhance the quality of patient education after SCI, which could improve self-management skills and prevent (long term) complications.

Keywords: spinal cord injury, secondary complications, mixed reality, patient education

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O4.5

FEASIBILITY OF VR TO PROMOTE HEALTH LITERACY IN PRIMARY CARE FROM THE HEALTH PROFESSIONALS VIEW: A MULTI-NATIONAL QUALITATIVE STUDY

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Objective: The development of health literacy is important in the rehabilitation of chronic pain and VR may be an effective medium for its development. This study aims to understand the usability and acceptability of a virtual reality-based pain education system for the facilitation of health literacy in two countries.

Methods: Semi-structured interviews were conducted with health professionals working in clinical practice in Australia and the UK to explore perceptions of feasibility. Data collection and analyses were informed by the Unified Theory of Acceptance and Use of Technology and the Integrated Model of Health Literacy.

Results: From 22 participants, the VR-based system was considered feasible in providing immersive experiential learning which addressed patient understanding and health-related communication.
Conclusion: VR appears to be perceived as an acceptable and feasible technology to support the development of health literacy in people with chronic pain. Its largest perceived benefit was its capacity to provide an immersive and entertaining alternative to conventional methods of pain education and shows potential in enhancing the plausibility and credibility of PSE.

Practice implications: Virtual reality is considered a feasible method of facilitating several aspects of critical health literacy and may serve as an alternative approach to making PSE information plausible and credible, via experiential learning. Feasibility of such a tool relies clinically on time available, social expectations of VR, and the role of immersive and experiential learning within the management of chronic pain.

Keywords: Virtual Reality, Health Literacy, Pain Science Education, Chronic Pain

O4.6

INCORPORATING EXTENDED REALITY INTO BRAIN INJURY REHABILITATION: INSIGHTS AND CHALLENGES FOR PATIENT-THERAPIST COMMUNICATION DURING THERAPY

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[1]*University of Canterbury,* [2]*University of Dundee*

Background: Extended Reality (XR) applications show promise in brain injury rehabilitation; however, concerns persist regarding its effect on the patient-therapist relationship, also termed the therapeutic alliance (TA). The TA is a key determent of rehabilitative success and relies on patient-therapist agreement on tasks and goals, and their interpersonal bond, with communication as a key component to this.
This study explored immersive Virtual Reality (VR) use in clinical settings for Acquired Brain Injury (ABI) rehabilitation, shedding light on how the introduction of XR technology can affect the TA. We examined patient-therapist interactions and alliance during VR use in rehabilitation, contrasting it with traditional rehabilitation, and uncovering challenges faced concerning the TA.

Method: The methodology employed involved observations of rehabilitation sessions with and without the use of VR, alongside conducting semi-structured interviews to capture patient and therapists' perceptions and experience of using VR during their rehabilitation session. Discourse analysis, predominantly conversational analysis, was used to examine the interaction among participants observed, with observations and interviews analysed using thematic analysis.

Results: Findings indicated change in patient-therapist interaction and communication when VR was introduced. There was a reduction in informal conversation, an increase in shared laughter, and more therapist verbal feedback was given. Despite the patients' inability to see their therapist through their head-mounted display, therapists continued to attempt eye contact and used guiding gestures. Interviews highlighted the importance therapists place on rapport-building, and both shared a reliance on one another for expertise and reassurance.

Conclusion: This research contributes novel insights on the impact of VR on the TA and possible design avenues of XR applications for ABI rehabilitation. The study's findings indicate that interaction is altered by VR use, creating challenges in the TA when using immersive VR. Findings can be used to inform future clinical use of VR and VE design that supports the vital TA, thus promoting successful rehabilitation. Future research might consider exploring alternative avenues, including different XR technologies and varied virtual environments. In addition, research should explore how to best facilitate seamless interaction between the patient and therapist, including how the incorporation of the therapist into the VE might support this.

Keywords: XR, Virtual Rehabilitation, Therapeutic Alliance, Acquired Brain Injury, Immersive Virtual Reality

PROJECTS IN THE SPOTLIGHT 1 JUNE 26, 2024

13:45 - 14:15

PS1.1 Integrating extended reality in rehabilitation: insights from the XREHAB project in belgium

PS1.2 A large over ground virtual suite (logvs) with integrated pedestrians for multifaceted virtual rehabilitation research and practice

PS1.3 VR-based interventions for neurocognitive and neurodevelopmental disorders: preliminary results of the vespa 2.0 project

PS1.1

INTEGRATING EXTENDED REALITY IN REHABILITATION: INSIGHTS FROM THE XREHAB PROJECT IN BELGIUM

Gudrun Nys[1], Ine Van der Cruyssen[1,2], Sarah Vercaemer[3], Arthur d'Hooghe[1], Thibaut De Tandt[1], Nathan Segers[4], Martijn Loth[4], Siska Vandemaele[2], Lode Sabbe[2,3], Jelle Demanet[1]

[1]*HITLab HOWEST,* [2]*HOWEST Occupational Therapy,* [3]*UZ Ghent Smart Space,* [4]*HOWEST MCT*

Background: For a number of years now, healthcare in Belgium has been under pressure due to various challenges, such as the cost of good healthcare and changes in demographic population. Extended reality (XR) is a transformative healthcare technology that is still being explored to assess its true potential for the healthcare sector. XRehab is a Belgian TETRA HEALTH project (September 2022 – August 2024) sponsored by VLAIO and coordinated by HOWEST (HITLab and Occupational Therapy) and UZ Ghent (Smart Space). The goal of XRehab is to facilitate the integration and development of XR applications in rehabilitation settings in Flanders. Thirty partners in Flanders joined this project and were part of the steering group.

Methodology and results: Our approach was threefold: First, we hosted XR workshops in which healthcare professionals became familiar with the diverse possibilities of XR for (i) motor rehabilitation, (ii) cognitive and visual rehabilitation, (iii) mental health and (iv) tele-rehabilitation. We also demonstrated XR applications that combined eye tracking, heartrate variability, sensors for motion tracking etc. Second, we produced a blueprint on how to adopt XR for rehabilitation and how to implement and develop XR for healthcare. Third, we co-designed XR use cases together with (i) hospitals, nursing homes and smaller practices involved in rehabilitation and (ii) XR companies interested in healthcare. These prototypes were developed by a multidisciplinary group of experimental and neuropsychologists, occupational therapists, XR developers, and MCT specialists. In a brainstorm session we performed during the first steering group of the project (January, 2023), four use cases were selected for co-creation. Following the development of these use cases, we created a dashboard for the therapist for streaming of the XR applications and for settings adjustment and data visualization. Finally, we performed test iterations with therapists and patients in order to demonstrate how XR projects are developed and improved in order to create efficient clinical solutions. Two XR prototypes were created for neurorehabilitation (visual and motor domain). The third prototype was created for occupational therapists to practice shopping in VR with patients. The fourth prototype is a multi-user VR experience in which a coach can train several clients at the same time in VR when doing motor routines. User testing of the prototypes will be performed with patients and therapists from February to May 2024.

Conclusion: The XRehab project has made initial steps in bridging the gap between advanced technology and practical healthcare needs, but has also created a community of multidisciplinary professionals committed to improving healthcare delivery. The combination of the workshops, the blueprint (which will be made freely available on our website), and the four XR prototypes give healthcare professionals the tools to get started with XR in practice.

PS1.2

A LARGE OVER GROUND VIRTUAL SUITE (LOGVS) WITH INTEGRATED PEDESTRIANS FOR MULTIFACETED VIRTUAL REHABILITATION RESEARCH AND PRACTICE

Bradford J. McFadyen[1], Andréanne K. Blanchette[1], Krista Best[1], Joris Boulo[1], The LogVS Team[2]

[1]Université Laval/Cirris, [2]Cirris/CRIR/INRIA

Background: Real world navigation of our complex daily environments requires simultaneous cognitive, mental, social and physical capabilities, that can be challenging to introduce safely and with precise outcomes in rehabilitation. Virtual reality (VR) provides a means to overcome this challenge. Beyond the simulated built environment, virtual environments (VE) can also simulate social interactions such as integrating with other pedestrians. Yet, the financial and human resources required to create VEs for virtual rehabilitation can be prohibitive and sharing of such resources is still limited. In addition, many VEs are limited in their focus and involve compromises to normal behaviour (e.g., using joysticks or treadmills instead of over ground displacement). A platform called the Large Over Ground Virtual Suite (Logvs) was designed to respond to the above-mentioned gaps. This platform was presented in its embryonic stage in a poster at the previous WCISVR meeting. The objective of the present project spotlight is to now show its greater potential and present the open-source context on which it is based with the hopes of opening the doors to further collaborative development and sharing.

Methodology: The Logvs platform consists of a virtual park with a space of over 100 m2 including a surrounding street environment. It was programmed using UnReal Engine (Epic Games, USA). The VE can be loaded onto a standalone HMD (currently we use Quest 2/Pro/3; Meta Platforms Inc., USA), for affordable, easy-to-use options. A Windows- or Android-based user interface provides control of different scenario parameters related to walking or rolling in a wheelchair and virtual pedestrian (MetaHuman agents) behaviour or characteristics (speed, physical interaction facial emotion, sex, age). Interaction with the HMD is provided through an autonomous wi-fi link.

Results and Conclusion: The full park scene can be partitioned to focus on smaller parts for restrained spaces (e.g., clinic hallways). Data from the HMD's inertial measurement units (orientation angles), inside-out tracking (linear position data) and eye tracking (when available) can be automatically collected. Continued developments of the virtual pedestrians include body expressions, oral communication, crowd behaviour and object manipulations. To democratize the Logvs platform with respect to VE content sharing within and across the many disciplines of the rehabilitation sciences, a GitLab platform with open access licensure based on the General Public License protocol has been set up. The goal is to make executable forms of Logvs available to researchers and clinicians and to promote further programming and development where all versions are openly accessible. While this is a challenge, the implications of such an approach for virtual rehabilitation research and practice are important and will hopefully help to reduce institutional and disciplinary boundaries and greater cooperative developments.

Keywords: VR platform, Mobility, Executive Functioning, Social Cognition, Open Source, Democratization

PS1.3

VR-BASED INTERVENTIONS FOR NEUROCOGNITIVE AND NEURODEVELOPMENTAL DISORDERS: PRELIMINARY RESULTS OF THE VESPA 2.0 PROJECT

Emanuele Maria Merlo [1], Salvatore Marco Pappalardo [2]

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Background: Virtual Reality (VR) represents a constantly growing field, whose applications range from gaming to medical devices. The VESPA Second Generation (VESPA 2.0) project represents a concrete application of VR declined to treatment of neurocognitive and neurodevelopmental disorders. Through the use of more than 150 specific cognitive tasks, from serious gaming to simulating everyday life experiences, the system enables patients to rehab cognitive deficits. The VESPA 2.0 System is flexible and scalable by design, as it can be deployed and used on several platforms. The fruition is possible through its mobile version (2.5D on Tablet PC) or at patients' homes (e.g., 2.5D on touch TVs). Semi- and fully-immersive implementations offer the possibility to exploit VR experiences through Head Mounted Displays (e.g., Meta Quest 2/3), or in a 3D/5D immersive VR CAVE in specifically designed environments available at clinical premises. Every experience is therefore customizable according to the patient. Scenarios are built on top of 3D environments, automatically adaptable to all the proposed devices. VESPA 2.0 deploys a Cloud Computing infrastructure, a multi-user Web Portal and tele-supervision. VESPA2.0 comprises olfactory stimulation and dynamic fruition devices as well.

Methodology: The application of the VESPA 2.0 System on 50 non-demented subjects affected by Mild Cognitive Impairment (MCI; mean ± SD age: 69.3 ± 6.5 years; 50.0% male) has allowed the emergence of significant results. The inclusion criteria concerned the diagnosis of MCI, age over 18 years old and the absence of dementias properly defined. The exclusion criteria concerned comorbidities with psychiatric disorders, typical parkinsonisms, and conditions related to speech disorders. Rehabilitation in VESPA 2.0 stimulates the patient's involvement and engagement and supports representing an infinitely patient and always available tutor.

Results: Through the application of the method it was possible to observe significant differences between T0 and T1, interspersed by the VESPA 2.0 System. The significant differences concerned different fields such as daily routine tasks concerning one's hygiene, nutrition, continence and mobility (Instrumental activities of daily living, IADL), as well as strictly cognitive skills (Montreal Cognitive Assessment, moca, Frontal Assessment Battery, FAB).

Conclusion: The VESPA 2.0 System has proven to be a flexible tool capable of producing a significantly positive impact on patients' health conditions. In particular, through the administration of the various tasks in question it was possible to notice significant differences between before and after compared to the diagnostic domains of reference. Further research is currently ongoing in order to improve the system's applicability and results. Thus, through the application of the system impact and verifiability of VR applications on heterogeneous patients will be demonstrated through tangible results.

Keywords: Clinical Psychology, Cognitive Rehabilitation, 3D, 5D, Virtual Reality, Olfactory Stimulation, Omnidirectional Treadmills

PROJECTS IN THE SPOTLIGHT 2 JUNE 27, 2024

16:15 - 16:45

PS2.1 Augmented reality exergames training for osteoporosis patients to improve balance, flexibility, muscle strength and engagement

PS2.2 Assessing the potential of “virtual reality multiplayer exergames” for people with mobility challenges to reach recommended physical activity levels

PS2.3 A game-based rehabilitation application for older adults with dizziness

PS2.1

AUGMENTED REALITY EXERGAMES TRAINING FOR OSTEOPOROSIS PATIENTS TO IMPROVE BALANCE, FLEXIBILITY, MUSCLE STRENGTH AND ENGAGEMENT

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Background: Osteoporosis is one of the largest musculoskeletal disorders in older people, resulting in almost ½ billion fractures annually, worldwide. In 2019, there were 4.3 million osteoporosis related fractures in Europe. Osteoporosis has a negative impact on a person's quality and quantity of life. Physical therapy is an established important non-pharmaceutical treatment which improves bone strength and reduces fall risk. However, engagement with, and adherence to a physical training programme is challenging for older adults, due to a lack of time, motivation and fear of falling. Virtual rehabilitation refers to the use of technology assisted rehabilitation (i.e., augmented reality (AR), virtual reality (VR), exergames). Virtual rehabilitation has been shown to be as efficient and more engaging than traditional rehabilitation, but its value among older people with osteoporosis is unclear. An exergame is defined as a game requiring exercising.
We hypothesise that technology-driven exergame physical therapy will result in better physical improvements and greater engagement compared to general supervised physical training sessions.

Aims: The primary aim is to assess the exergame effectiveness in improving balance and muscle strength to reduce fall risk among people with osteoporosis.
Secondary outcomes include flexibility and pain. We will also examine the emotional impact of our intervention on fear, confidence, enjoyment, and engagement.

Methods: Our study is a prospective controlled clinical trial to assess the impact of our intervention on the nature and quantity of change across a number of established physical and emotional metrics.
Five physical therapy exercises targeting older adults with osteoporosis were designed and approved by a physiotherapist, occupational therapist and two rheumatologists at Galway University Hospital. These standard exercises were then translated into five AR exergames, whose design was based on the findings from a systematic review of virtual physical rehabilitation and existing guidelines.

Patients with a DXA (Dual-energy X-ray Absorptiometry) diagnosis of osteoporosis will be offered participation in this study. Approval has been obtained from our clinical research ethics committee and written informed consent will be required for participation. Enrolled participants will engage with 12 sessions of physical exercise, each of 20-minute duration. Participants will be divided into two groups: an intervention group practicing AR-exergames using an AR-headset (i.e., Microsoft Hololens 2) and a body tracking camera (i.e., Azure Kinect); and a control group practicing the standard set of exercises.

We will evaluate the short-term impact on muscle strength, mobility, flexibility, pain, and feedback (immersion, engagement, and appreciation of the virtual approach) as well as long-term changes in body shape, BMI, bone fat and lean mass assessed by DXA and a 'smart' scale).
Our clinical trial will commence in June 2024.

Keywords: Exergame, Virtual Rehabilitation, Augmented Reality, Osteoporosis, Physical Therapy

PS2.2

ASSESSING THE POTENTIAL OF "VIRTUAL REALITY MULTIPLAYER EXERGAMES" FOR PEOPLE WITH MOBILITY CHALLENGES TO REACH RECOMMENDED PHYSICAL ACTIVITY LEVELS.

Mahmudul Hassan[1], Zahid Iqbal[1]

[1]Teesside University

Regular exercise is critical for individuals with disabilities to maintain health and mitigate chronic diseases. Despite its importance, many faces significant barriers to engaging in physical activity. Limited accessibility to exercise facilities and equipment, coupled with a lack of motivation and societal stigma, hinder participation. Sports England's study underscores these challenges, revealing stark disparities in activity levels between disabled and non-disabled individuals. Without adequate accommodations and support, disabled individuals struggle to access suitable exercise opportunities, increasing their vulnerability to health risks. Addressing these barriers is essential to promoting inclusivity and enabling disabled individuals to reap the benefits of regular exercise.
Recognizing the importance of exercise and the challenges faced by mobility-impaired individuals, particularly those reliant on wheelchairs, we've developed a range of VR exergame prototypes tailored to support differently abled individuals in engaging in physical activity, alleviating stress, and facilitating social interaction. Utilizing technology like head-mounted displays and hand-tracking systems, users are immersed in virtual environments where they can participate in activities such as boat rowing, boxing, and rock climbing (both in single user and multiuser mode). These interventions, backed by their effectiveness in therapy and fitness, aim to address the unique needs of mobility-impaired individuals. Through impact studies, our objectives are to assess the physical, psychological, and social benefits of these exergames, evaluating factors such as user engagement, multiplayer participation, and fitness tracking data to gauge their effectiveness. Additionally, we aim to identify and address challenges in customizing VR exergames specifically for mobility-impaired users, ultimately striving to enhance their overall well-being by promoting physical health, emotional balance, and social connectivity.
Our prototypes underwent initial brief testing with both wheelchair-bound and non-wheelchair-bound individuals, refining them based on feedback. We've conducted preliminary market research and secured verbal commitments from various partners, including National charities for inclusive sports, Private charities for disabilities, NHS (UK), Student Unions, parents, and physiotherapists, for collaborative co-creation.
Our future goal is to create standout products by collaborating with wheelchair users and experts, ensuring personalized solutions. These products will adapt to diverse disabilities, addressing challenges like accurate calorie counting. Innovation drives us as we build a vibrant community for enhanced social interaction, user engagement, and retention.

PS2.3

A GAME-BASED REHABILITATION APPLICATION FOR OLDER ADULTS WITH DIZZINESS

Nathan Pickle[1], Riley Sheehan[1], Garrett Tuer[1], Linda D'Silva[2], Paulien Roos[1]

[1]CFD Research, [2]University of Kansas Medical Center

Background: An estimated 35% of adults in the United States have vestibular dysfunction requiring medical attention, and the incidence increases with age. Unaddressed vestibular hypofunction is associated with symptoms of dizziness/imbalance, visual blurring with head movement, and postural instability increasing risk of falls. Vestibular rehabilitation is effective in reducing dizziness in people with vestibular dysfunction. However, to reduce dizziness and improve gaze stability, vestibulo-ocular (VOR) exercises must be performed accurately and consistently. Less than half of people who are prescribed vestibular rehabilitation perform their exercises as prescribed. VestRx is a mobile application developed to address these issues and improve outcomes of vestibular rehabilitation.

Methodology: We have developed a mobile application, VestRx, which provides at-home vestibular rehabilitation exercises in a game-based interactive format. The patient's motion is tracked using the front-facing camera on the mobile device and is used to control the games. Games are included for VORx1, balance, and weight shift exercises. The app includes machine learning algorithms that have been developed to identify the most commonly made mistakes by patients during VOR exercises. A story line and game scores have been implemented to improve enjoyment. Physical therapists can remotely monitor their patients through a web portal and update exercise prescriptions when needed. The app was tested in a laboratory setting as part of a clinical trial where 40 patients with vestibular hypofunction (20 females; mean age 67±5.7 years) performed a rehabilitation session with the app and one without the app.

Results: The main findings were that participants performed exercises more consistently and closer to the prescribed settings for range of motion and frequency, when using the app. With the weight shifting exercises, participants shifted their weight further out when using the app. The participants improved performance when feedback was provided. Questionnaire responses showed that the majority of participants enjoyed using the app and would find it useful for their rehabilitation.

Conclusion: An application has been developed to improve accuracy and compliance of vestibular rehabilitation. An initial clinical trial showed that patients perform the exercises correctly when using this app and enjoy using the app. While the team is still developing the app, a commercial version with limited features is currently on the market and used by initial physical therapy clinics. The goal is to expand the machine learning capabilities and game portfolio to improve patient engagement in their rehabilitation, thus improving patient outcomes.

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PROJECTS IN THE SPOTLIGHT 3 JUNE 28, 2024

11:45 - 12:00

PS3.1 Exploring the virtualist's role – insights and examples from the Workplace

PS3.1

EXPLORING THE VIRTUALIST'S ROLE – INSIGHTS AND EXAMPLES FROM THE WORKPLACE

Linda Garms[1]

[1] *Department of Surgery, Radboud University Medical Center*

Introduction: Virtual Reality (VR) therapy has emerged as an effective pain management tool, especially for procedural and acute pain. Despite the growing body of evidence supporting its efficacy, the integration of VR therapy into clinical practice, especially within hospital settings, presents several challenges. Among the most significant barriers to its widespread adoption are the needed technical and organizational support and the adequate training for healthcare providers. In response to these obstacles, our institution has pioneered the creation of a novel position, termed 'Virtualist', within our VR consultancy service named 'VRtoGO'.

Methods: To address the requirements of healthcare providers and initiate a VR therapy movement within our hospital, we established 'VRtoGO'. This service is supported by a multidisciplinary team comprising a research coordinator, who assumes the role of a virtualist, a medical doctor engaged in PhD research on the individualization of VR therapy (VRx), a program manager, and a supervising medical specialist. VRtoGO initiated outreach to various wards within the Radboudumc, providing essential background information on the utility and scientific support for VR therapy. Following an introductory workshop, healthcare providers, predominantly nurses, were encouraged to request VR therapy for their patients. Requests for VR therapy can be made via a web portal, email, or telephone. In most instances the VR therapy is applied the same day as requested. The primary application utilized offers patients a range of relaxing activities including simple games, short films, or guided meditation sessions. Patients are advised to use VR therapy at their discretion, with a recommended limit of three sessions per day and a maximum duration of 30 minutes per session to mitigate the risk of adverse effects.

Results: The primary objective for most inpatients utilizing VR therapy is distraction from pain, affording them an opportunity to relax and for a moment escape from the hospital environment. VR therapy is frequently requested for patients requiring wound care, experiencing post-amputation pain, recovering from serious accidents, or managing cancer-related discomfort. There are several illustrative cases of patients who underscore the positive impact of VR therapy on patient experience.
However, challenges persist in the maintenance and expansion of 'VRtoGO', with variations in service uptake across departments and concerns regarding sustainable funding. Based on our experience, we propose several recommendations for other hospitals considering VR implementation. These include promoting independence within wards, which requires the engagement of dedicated nurses who advocate VR therapy for their patients. Furthermore enhancing provider education on VR benefits, integrating VR into clinical pathways, and establishing patient feedback mechanisms to refine VR applications and underline its value.

POSTER SESSION 1
JUNE 27, 2024
12:30 - 13:45

P1-1 Application of an existing virtual reality-based pain management training in persons with spinal cord injury associated pain – a pilot study

P1-2 Innovating rehabilitation: integrating telerehabilitation to enhance access to services in benin

P1-3 Neural processing of optic flow during obstacle negotiation in virtual reality: an eeg study

P1-4 Validity of gait and mobility outcomes using an augmented reality (AR) headset compared to markerless motion capture

P1-5 VR targeting communicative competence and participation in people with aphasia

P1-6 Pulmonary and physical virtual reality exercises for patients with blunt chest trauma: a randomized clinical trial

P1-7 The societal impact: the next step in the evaluation of virtual rehabilitation

P1-8 Design and evaluation of virtual game for relaxation breathing technique

P1-9 The interaction of walking, lexical decisions and visual distraction among older adults in virtual reality settings

P1-10 Examining the role of interac6ve technologies in pediatric occupa6onal therapy: insights from a narra6ve review

P1-11 Virtual reality in cognitive rehabilitation: neural mechanisms from fmri research on the ecological stimulation of attention

P1-12 Feasibility, acceptability, and usability of a tele-rehabilitation combining immersive virtual reality exercises and therapeutic Education for persistent non-specific neck pain: a mixed-methods pilot study

P1-13 3D virtual reality prism adaptation simulation system for hemispatial neglect

P1-14 Barriers for the adoption of serious games in physical rehabilitation therapy

P1-15 Studying the effects of task-intrinsic stress on cognitive-motor performance using virtual reality

P1-16 Enhancing visual and attentional rehabilitation with xr and eye tracking: innovations from the XREHAB project

P1-17 Mindflow mastery: virtual voyage to teen tranquility - elevating emotional wellness with e-learning and VR adventures

P1-18 Feasibility of implementing virtual reality in a community organization

P1-19 Towards nonverbal measurements of embodiment of real-world orthoses using virtual limbs: a study protocol

P1-20 Evaluating virtual reality high-intensity interval training in healthy young adults: physiological and psychological impacts from a preliminary pilot randomised controlled trial

P1-21 Development of a virtual clinic for children with rare diseases

P1-22 Dynamic assessment of everyday communication using virtual reality: proof of concept for persons with aphasia (dcom-VR)

P1-23 At-home VR treatment for patients with chronic musculoskeletal pain: a cluster randomized controlled trial

P1-24 The interaction of automatic and volitional motor tasks during postural control and cognitive challenges in virtual reality

P1-25 Development of virtual reality case scenarios for pain science clinical reasoning education

P1-26 Enhanced ecological validity of acoustic voice analysis through virtual reality

P1-1

APPLICATION OF AN EXISTING VIRTUAL REALITY-BASED PAIN MANAGEMENT TRAINING IN PERSONS WITH SPINAL CORD INJURY ASSOCIATED PAIN – A PILOT STUDY

Joost F. Baardman [1], Christel van Leeuwen [1], Marcel Post [1], Janneke Stolwijk-Swüste [1]

[1]*Rehabilitation Centre De Hoogstraat*

Background: Pain is common after spinal cord injury (SCI) and considerably impacts mental well-being. Pharmacological treatments have limited effects and notable side effects and therefore non-pharmacological treatments are increasingly investigated. Reducept is a VR pain education and pain management training, designed for people with chronic pain. This pilot study investigates the feasibility and possible effects of the Reducept training in individuals with SCI-associated pain.

Methodology: A pilot study with pre- and post-intervention comparison was conducted with inpatients and outpatients of rehabilitation center De Hoogstraat, Utrecht, The Netherlands, between June 2022 and July 2023. Reducept was provided for a four week period. User experiences and feasibility were assessed with post-intervention interviews. Questionnaires before and after the intervention examined pain, quality of life and psychological characteristics (pain catastrophizing, anxiety and depression, self-efficacy, passive coping).

Results: People with SCI (15 outpatients, 4 inpatients, median 4 years after onset of SCI) were positive about the intervention and completion of the training was feasible for nearly all participants, though timing of training was more challenging for inpatients. Pain scores on a 0-10 point scale were reduced with 1.00 (p=0.021) after intervention. However, satisfaction with physical health also decreased significantly with 1.00 (p=0.026) on a 0-10 point scale. A trend was found in reduction of pain catastrophizing-rumination (p=0.06), but no other significant differences were identified. Results must be interpreted carefully due to limitations, mainly related to the small study population.

Conclusion: Based on this pilot study, implementing Reducept as a VR pain education and management training is feasible and might have positive impacts on pain and pain catastrophizing. Therefore, Reducept will be applied in standard care in our center from 2024. We advise further research of its effects on pain and physical quality of life.

Keywords: spinal cord injury, virtual reality, pain management

P1-2

INNOVATING REHABILITATION: INTEGRATING TELEREHABILITATION TO ENHANCE ACCESS TO SERVICES IN BENIN

Martin Jacobs[1], Bruno Bonnechère[2,3,4]

[1]*Humanity & Inclusion,* [2]*REVAL Rehabilitation Research Center, University of Hasselt,* [3]*Data Science Institute, University of Hasselt,* [4]*Department of PXL – Healthcare, PXL University of Applied Sciences and Arts*

Background: Healthcare accessibility, particularly for rehabilitation services, remains a critical concern in low-income countries (LICs) such as Benin. The shortage of healthcare professionals poses significant challenges to delivering comprehensive care. To address these limitations, this study investigates the potential of mobile health (mHealth) technologies for rehabilitation in Benin. Specifically, it focuses on smartphone and tablet-based interventions aimed at managing the aftermath of traffic accidents. The rising prevalence of such accidents poses significant risks to the healthcare system. These conditions not only diminish the quality of life but also impede access to gainful employment opportunities for these patients.

Methodology: The integration of telerehabilitation into traditional rehabilitation service provision to improve access to rehabilitation services involved several key steps. Humanity & Inclusion (HI) developed OpenTeleRehab, an open-source, multidisciplinary telerehabilitation software recognized as a Digital Public Good. Training and capacity building sessions were conducted locally to equip healthcare professionals and rehabilitation practitioners with the necessary skills to use OpenTeleRehab effectively. These sessions covered technical aspects of the software, best practices for telerehabilitation delivery, and considerations for integrating telerehabilitation into traditional service provision.

A pilot implementation of telerehabilitation services will be conducted in 3 rehabilitation facilities across the country with 36 patients. This pilot aims to assess the feasibility and acceptability of integrating telerehabilitation into traditional service provision. Data about both patients and clinicians' experiences as well as operational challenges will be collected and analyzed to inform further refinements and scale-up efforts.

Results: Continuous evaluation and monitoring of the integrated telerehabilitation services will be carried out to identify areas for improvement, and ensure quality of care. Outcome measures will include accessibility of rehabilitation services, and patient satisfaction. Based on the findings from this pilot study, HI plans to scale up the integration of telerehabilitation into traditional service provision. This involve expanding the use of OpenTeleRehab to additional rehabilitation facilities and regions, while addressing any identified barriers or challenges.

Conclusion: Telerehabilitation service provision represents a promising avenue for enhancing healthcare accessibility in low-income countries like Benin. The comprehensive methodology employs in this study, including training sessions and pilot implementations, will provided valuable insights into the feasibility and acceptability of telerehabilitation integration. mHealth solutions can enhance rehabilitation access and promote equitable healthcare for all individuals, regardless of their socioeconomic status or geographic location.

Key Words: Telerehabilitation, low-income countries, feasibility, implementation, healthcare coverage

P1-3

NEURAL PROCESSING OF OPTIC FLOW DURING OBSTACLE NEGOTIATION IN VIRTUAL REALITY: AN EEG STUDY

Marco A. Bühler[1], Sylvain Baillet[1], Bradford J. McFadyen[2], Joyce Fung[1], Anouk Lamontange[1]

[1]McGill University, [2]Université Laval

Introduction: Stepping over obstacles is an important task for community ambulation. It involves processing visual information to guide precise locomotor adjustments. During locomotion, optic flow provides information about self and obstacle motion that pedestrians can use to estimate their relative distances with respect to obstructions. Previous studies have examined the neural mechanisms involved in obstacle negotiation during treadmill walking without optic flow. In the present study, a virtual reality (VR) based obstacle negotiation task with electroencephalography (EEG) was used to gain insight into the neural mechanisms underlying this task in the presence or absence of optic flow.

Methods: Healthy young (18-29 years) participants (n=25) were immersed in a VR (HTC Vive Pro Eye) environment where they performed obstacle negotiation during treadmill walking. The task involved stepping over virtual cylinders (I) with optic flow, where self-motion visual cues were provided, and (II) without optic flow, where the scene was deprived of any self-motion visual cues (Fig. 1 - A & B). Brain activity and locomotor movements were recorded, respectively, using a 64-channel EEG system (Brain Vision) and a motion capture system (Vicon). EEG signals were high-pass filtered (1Hz), high noise segments/channels were removed after visual inspection and eye components were removed after ICA decomposition (AMICA). Epoch grand averages were obtained from the Pz electrode and used to examine event-related spectral perturbations across conditions.

Results: EEG results revealed distinct patterns of cortical activity during obstacle negotiation. In the absence of optic flow, a phasic alpha desynchronization was observed between 380 and 2500 ms following obstacle presentation (Fig. 1 – C). When optic flow was present, there was evidence of a persistent alpha desynchronization (Fig. 1 – D & F). The differences in cortical activity between the two conditions highlight the importance of optic flow in the control of obstacle avoidance. The phasic alpha desynchronization in the absence of optic flow further suggests a task-specific cortical response to obstacle presentation and motor planning. Conversely, the chronic alpha desynchronization in the presence of optic flow may reflect ongoing processing related to continuous visual feedback and attention.

Conclusion: Our study demonstrates distinct alpha activity patterns over the parietal cortex during an obstacle negotiation task with and without optic flow. This parietal activity is likely related to visual processing and the planning of locomotor adaptations. Further research is warranted to elucidate the specific neural circuits and mechanisms underlying these cortical activity patterns and their implications for the design of VR-based evaluation and rehabilitation protocols.

Keywords: EEG, Obstacle Avoidance, Optic Flow, Virtual reality, Locomotor adaptations

P1-4

VALIDITY OF GAIT AND MOBILITY OUTCOMES USING AN AUGMENTED REALITY (AR) HEADSET COMPARED TO MARKERLESS MOTION CAPTURE

Pieter van Doorn[1], Jara van Bergem[1], Melvyn Roerdink[1]

[1]*Vrije Universiteit Amsterdam*

Background: In rehabilitation, measuring and monitoring mobility is key to gain insight in the progress of recovery. However, objective assessments of mobility in the lab or clinic are often expensive, time-consuming and provide only a snapshot of the mobility of the patient's mobility. Augmented Reality (AR) technology presents a promising solution by offering a platform for objective monitoring of patient mobility during exercises, thus reducing the burden on the patient and healthcare provider. RealityDTx©, a CE-marked software application designed for AR, provides various exergames that engage patients in movements such as walking, turning, and squatting while collecting 3D positional and rotational data from the headset. Previous studies have demonstrated the validity of using the AR headset to extract gait and mobility outcomes during standardized clinical tests, but its validity during exergaming remains unexplored. In this study we will investigate the validity of gait- and mobility outcomes derived from the AR-headset during exergaming compared to a validated markerless motion capture system, Theia3D.

Methodology: Fifteen to twenty healthy adults will participate in a series of exergames using RealityDTx© software. Their movements will be simultaneously captured by a validated markerless motion capture system, Theia3D and the AR-headset sensors. Both datasets will be translated into quantitative (e.g., steps, walking distance, turns, squats) and qualitative (e.g., step length, cadence, gait speed, turn duration and velocity, squat duration, velocity, and depth) gait and mobility parameters. The concurrent validity of these parameters will be tested using the intraclass correlation coefficient for absolute agreement (ICC); ICCs above 0.60 and 0.75 represented good and excellent agreement, respectively and the limits of agreement (LoA) obtained with a Bland-Altman analysis. Results: Data collection will commence in February 2024, with results expected to be available before June 2024. The findings will be presented at the WCVR.

Conclusion: The results of this study will provide valuable insights into the validity of gait and mobility outcomes obtained from an AR headset during exergaming, contributing to the advancement of objective gait and mobility assessment in rehabilitation settings.

Keywords: Validity, Gait, Mobility, Monitoring, Exergaming

P1-5

VR TARGETING COMMUNICATIVE COMPETENCE AND PARTICIPATION IN PEOPLE WITH APHASIA

Rimke Groenewold[1], Hilde Bosschers[2]

[1] University Medical Center Groningen, [2] Siza

Background: Aphasia is a language disorder due to brain damage. Since language is crucial for social participation, aphasia significantly impairs a person's everyday life functioning (Code & Herrmann, 2003). While the primary goal of aphasia therapy is to help people with aphasia (PWA) communicate in everyday life, there are currently no materials available aimed at improving everyday communication skills (Groenewold & Bosschers, 2023). Despite the potential of VR for this purpose, its application in aphasia therapy is limited (Devane et al., 2023). In a previous project, pilot VR materials were developed in collaboration with PWA, Speech Language Therapists (SLTs) and researchers. These materials were evaluated by PWA (n=9) and SLTs (n=11). The current project (Participating with Aphasia in Practice; MAP) aims to further develop and implement the VR materials for aphasia treatment.

Methodology: MAP is a two-year project that applies a participatory action research (PAR) approach, involving PWA and SLTs throughout the entire project. The project consists of three phases. In phase 1, the results of the pilot evaluation results are processed and used as input for improved and additional materials. These will be distributed and evaluated by a new group of PWA and SLTs. The results of this evaluation round will serve as input for phase 2. In phase 2, a second round of improvement and development will take place and instructions for SLTs will be developed. In phase 3, the final materials and instructions will be distributed to SLTs in various healthcare settings. In this phase there is room for final adjustments and making the materials future-proof.

Results: The evaluation of the pilot materials showed that both PWA and SLTs see potential in the application of VR in aphasia therapy. PWA indicated, among other things, that it helps to practice with everyday situations, that VR feels natural and that it is easy to participate in the situation. SLTs noticed that it is easier for PWA to give an appropriate response in the VR situation than in a situational exercise with an SLT, where it is more obvious that they are 'pretending'. SLTs also praised the realistic nature of the materials. Since MAP is in its preparatory phase, no final data have been collected. A prioritization of the input from PWA and SLTs and an overview of technical limitations and challenges in treating aphasia will be presented. The hoped-for feedback from experts is an important source of information in the further development process.
Conclusion: VR may offer SLTs a unique opportunity to address communication and participation in a way that has hardly been explored (Devane et al., 2023). Therefore, the MAP project is innovative and highly needed.

Keywords: aphasia, VR, speech-language therapy, communicative competence, everyday communication

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P1-6

PULMONARY AND PHYSICAL VIRTUAL REALITY EXERCISES FOR PATIENTS WITH BLUNT CHEST TRAUMA: A RANDOMIZED CLINICAL TRIAL

Tjitske D. Groenveld[1], Indy G.M. Smits[2], Naomi Scholten[1], Marjan de Vries[1], Harry van Goor[1], Vincent M.A. Stirler[1] [3]

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Background: Adequate pain relief, early restoration of breathing, and rapid mobilization pose a clinical challenge in patients with blunt chest trauma. Virtual reality (VR) has the potential to achieve these three interrelated treatment objectives with enhanced self-efficacy and autonomy of patients and limited support by clinicians.
Objective: To assess the effectivity of breathing and physical exercises using VR on the pulmonary recovery of patients with blunt chest trauma at the ward.

Methods: A randomized controlled trial was performed. The control group received usual physiotherapy consisting of breathing and physical exercises. The VR group was instructed to perform these exercises using VR. The VR breathing exercises were comparable to usual physiotherapy. The VR physical exercises consist of several games through which patients are challenged to reach out to objects while involving their arms, head and trunk. Primary outcome was vital lung capacity at day 5 or earlier at discharge. Secondary outcomes were patient mobility, clinical outcomes, pain, activities of daily living, patient reported outcome measures, and barriers and facilitators towards implementation.

Results: The study was prematurely ended due to enrolment failure combined with poor protocol adherence to exercises in both groups. 27 patients were included. Vital lung capacity at 5 days (or last measurement) was equal between groups with 1830mL (±591) and 1857 mL (SD 435) in the control and VR group respectively. No differences were observed in secondary outcomes. Patient interviews showed positive attitudes towards the use of VR. However, patients did not experience added value over usual care and reported that better integration in treatment and the hectic hospital environment could improve use of the VR exercises.

Conclusion: The suitability of patients to use VR therapy in a hospital (trauma) ward setting is lower than generally expected. Effective application of VR therapy requires professional guidance and needs thorough alignment with clinical practice.

Keywords: Virtual Reality; pulmonary rehabilitation; blunt thorax trauma; acute pain

P1-7

THE SOCIETAL IMPACT: THE NEXT STEP IN THE EVALUATION OF VIRTUAL REHABILITATION

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Background: Limited resources and capacity in healthcare force us to make choices about which innovations will be implemented. When evaluating health technologies to make decisions about their implementation, people often forget to consider their societal impact. Knowing this societal impact, helps us to make informed choices. A method to assess the societal impact of health technologies is the Social Return on Investment (SROI) methodology. The SROI methodology measures a broad concept of value, including financial, social and environmental costs and outcomes. This methodology results in an SROI ratio, which shows the social return of a health technology in euros compared to the investment. The aim of this presentation is to show how we can take the next step in evaluating virtual rehabilitation by assessing the societal impact.

Methodology: As a case study, we focus on the societal impact of ALS home-monitoring module within Roessingh Center for Rehabilitation (RCR). This module is being used for monitoring people with amyotrophic lateral sclerosis (ALS) from home and is based on the ALS home-monitoring and coaching app from the Dutch ALS center. In the module of this case study, the same care protocol is implemented as in the ALS app of the ALS center. The treatment team includes a care coach who monitors the individuals' progress and takes action if necessary based on the data gathered.

For this case study, we spread online questionnaires to and conducted interviews with people who have ALS and use the module and with healthcare professionals who use the module. During the interviews and questionnaires, we focused on the inputs and outcomes of the different stakeholders when using ALS home-monitoring, which was used to draft the SROI.

Results: Figure 1 shows an overview of the SROI results. The stakeholders Telerehabilitation and Health insurance are silent stakeholders. In the case of Telerehabilitation, the input is cancelled out against the outcome. For the Health insurance, the costs would also be incurred without using ALS home-monitoring. The SROI ratio of 1.08 means that: every euro invested in using ALS home-monitoring now will be worth €1.08 in 5 years' time.

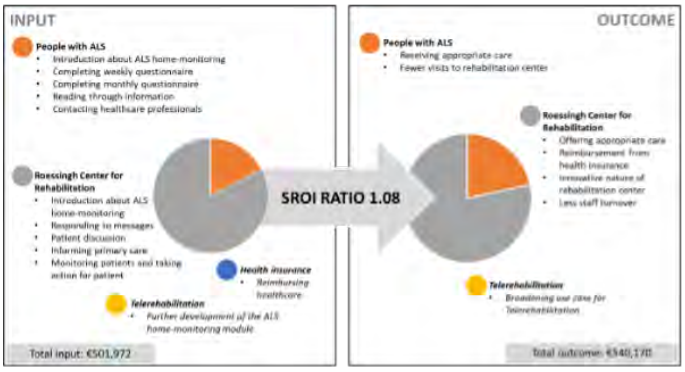

Figure 1: Overview of SROI including input and outcome per stakeholder Conclusion:

The SROI shows us that from the societal perspective, ALS home-monitoring is slightly profitable. Implementing this module leads to, among other things: appropriate care, less patient visits and less staff turnover. However, despite the fact that we got input from those directly involved, we also had to make some assumptions regarding the outcomes while conducting the SROI. For further development of this SROI, empirical data is needed. Altogether, this case study shows us the added value of the SROI methodology compared to traditional evaluations when evaluating health technologies, which is the importance of focusing on all stakeholders and also on the non-monetary costs and benefits.

Keywords: Telerehabilitation, societal impact, home-monitoring, Social Return on Investment, evaluation

P1-8

DESIGN AND EVALUATION OF VIRTUAL GAME FOR RELAXATION BREATHING TECHNIQUE

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Background: Research shows that breathing techniques fundamentally reduce stress and anxiety levels [1]. In the context of mental health care virtual reality (VR) appears to be a useful tool, which can be also used in a form of relaxation breathing techniques. In combination with biofeedback, VR offers the possibility of practicing breathing in a more immersive and less distracting environment, allowing easier training of respiratory synchronization with the selected breathing rhythm [2].
This study aims to test the usability of a newly developed VR Breath application, created as part of a larger project devoted to the development and use of new e-mental health tools in the treatment of mental illness.

Methodology: VR Breath is a self-guided application that allows the user to learn and practice relaxation breathing in an immersive environment using voice instructions, visual cues, and respiratory biofeedback (e.g. tree growing if the user is breathing in the given rhythm). First, a prototype of the application in a forest environment was created (Fig.1) and repeatedly tested by team members. This tool is meant primarily for patients with anxiety disorders for whom breathing techniques appear to be very effective [3].

Results: In an ongoing pilot study, the usability of the newly developed application VR Breath is tested in 15 patients with various anxiety disorders. The patient's perceived anxiety is measured by subjective scales (STAI-6) before and after 15 minutes of relaxation in VR. The patients evaluate their experience and overall comprehensibility using the System Usability Scale.

Conclusion: The main aim of this study is to examine the feasibility of the created VR application. A detailed description and preliminary findings will be presented at the conference. Different VEs will be designed based on focus groups with the tested patients for a future validation study comparing the potential effects on anxiety with a control condition (VR art-therapeutic game).

Acknowledgement: The study is a part of the project „Research of Excellence on Digital Technologies and Wellbeing CZ.02.01.01/00/22_008/0004583“ which is co-financed by the European Union.

Keywords: Virtual Reality; Breathing; Relaxation; Biofeedback; Stress reduction

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P1-9

THE INTERACTION OF WALKING, LEXICAL DECISIONS AND VISUAL DISTRACTION AMONG OLDER ADULTS IN VIRTUAL REALITY SETTINGS

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Background: Safe walking is crucial to older adults' ability to master everyday interactions, but it is also a complex cognitive process, often performed alongside other tasks. Little is understood about how gait interacts with concurrent tasks, e.g. language and visual processing.
We created a virtual reality (VR) paradigm where we gradually increased cognitive load: lexical decision (LDT), walking (i.e., self-paced treadmill) and visual processing (i.e., inhibition of visual distraction). Each task is completed in a single-task condition and integrated in an ecologically valid multitask.

Methodology:
Participants
Eight older adults between ages 55-80, dominant English speakers with normal vision and no neurological or physical deficits. To date, we have tested one patient with chronic stroke (CS), who was more than six months post stroke, with no agnosia or neglect.
Session 1: Single-Task+
Participants completed the LDT on a large screen, showing the letter strings overlayed on a static image of a city scape. Some trials included visual distractors (i.e., red square).
Session 2: Multitask
Participants performed a multitask, involving the same LDT during walking on a self-paced treadmill that creates an immersive experience by synchronizing the VR city scape with gait speed. Movements were captured with a Vicon system.
Analysis
We analyzed correct reaction times (CRT) and response error rate (ER) on the LDT using linear mixed-effects models. Changes in gait speed (m/s) were analyzed with an ANOVA comparing baseline walking speed to walking while completing the LDT or LDT with visual distractors.

Results: LDT. Overall, participants had higher ER ($p<.01$) and longer CRT ($p<.01$) in the multitask than the single-task+ session. Both words and nonwords were responded to faster and more accurately than pseudowords (all $p<.01$). For RT, there was a significant interaction of session and word type ($p<.01$), See Figure 1.

Gait. Experimental manipulations yielded no changes in gait speed.
Exploratory Analysis. A regression analysis of the CS patient's performance yielded a similar pattern as in OAs where words and nonwords were responded to faster and more accurately than pseudowords (all $p<.01$). CRT were slowed by visual distractors ($p=.02$), while ER was unaffected. Responses were slower ($p<.01$), but comparably accurate in the single-task and multitask session. The gait analysis suggests that the patient sped up as tasks were added.

Conclusion: We examined how OAs, healthy and with CS, manage demands of lexical processing, visual distraction and gait in a VR multitask. While LDT patterns remain consistent with the addition of concurrent tasks, performance degrades during walking. The absence of task-adaptation with increased cognitive load points to the robustness of these mechanisms among healthy OAs; however CS patients may have a lower threshold to engage in task prioritization in the interest of safety.

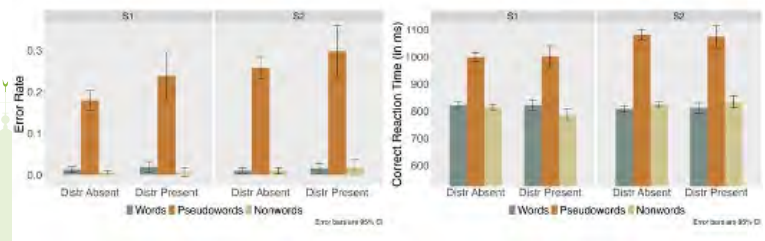

Figure 1. Error rates (left) and correct reaction times (right) for healthy older adults across experimental conditions

P1-10

EXAMINING THE ROLE OF INTERACTIVE TECHNOLOGIES IN PEDIATRIC OCCUPATIONAL THERAPY: INSIGHTS FROM A NARRATIVE REVIEW

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Keywords: Pediatric Occupational Therapy, Interactive technology, Virtual Reality, Video Games, Skills Development.

Background: Occupational Therapy (OT) helps children with disabilities to enhance their participation in daily activities. Although assistive technologies such as communication and mobility aids are commonly used, little is known about the use of interactive technologies such as virtual reality, video games, and robotics for therapeutic assessment, intervention, and monitoring in pediatric OT. These technologies offer potential benefits for motor skill development and participation in meaningful activities, but their interaction methods make them less applicable to targeting the occupational participation focus of pediatric OT interventions. The objective of this narrative review is to describe the current state of literature on interactive technology integration in pediatric OT.

Methodology: A narrative review provides a comprehensive approach to summarizing existing knowledge. Using the Scale for the Quality Assessment of Narrative Review Articles (SANRA) guidelines, we searched MEDLINE, CINAHL, and Web of Science for articles published between 2013 to 2023 using interactive technologies in OT for children aged 3 to 18- years. After abstract and full-text review, two researchers independently extracted data for descriptive and numerical analysis.

Results: 79 papers were included. 68% of papers focused on enhancing motor skills, while 13% focused on social/emotional development (13%) and 5% concentrated on chronic pain management. Virtual or augmented reality was used in 48% of studies, predominantly with children with cerebral palsy or other neurodevelopmental disorders. iPad/computer applications were used in 16% of studies, mainly for children with dysgraphia. Robotics (10%) and wearable devices (8%) were mostly employed in studies addressing mobility and physical impairments. 18% of studies involved a combination of different interactive technologies. Most research methodologies were experimental or quasi-experimental (51%), while 28% were comparative, and 21% were descriptive (including 3% of qualitative designs for the latter). 58% of studies tested an existing technology, 29% of studies developed or evaluated new technology, 9% summarized existing research, and 4% focused on therapist or user perspectives of interactive technology use.

Conclusion: Interactive technology use in pediatric OT focuses on motor skills despite the profession's more holistic focus on sensorimotor coordination, activities of daily living, and cognitive and social development. The role of interactive technology use in pediatric OT requires further exploration, as findings suggest the need for more studies to diversify therapeutic goals and expand scope. We are currently building on these initial findings in a scoping review to describe facilitators and barriers to interactive technology use in pediatric OT, illuminate gaps in the knowledge base and inform subsequent research efforts.

P1-11

VIRTUAL REALITY IN COGNITIVE REHABILITATION: NEURAL MECHANISMS FROM FMRI RESEARCH ON THE ECOLOGICAL STIMULATION OF ATTENTION

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Background: Attention deficits are among the most common and debilitating symptoms following any kind of acquired brain injury. Previous interventions aimed at rehabilitating attention through training have suffered from limited transferability of treatment improvements. Consequently, Virtual Reality technology is increasingly used in the rehabilitation of attention deficits due to its capacity to realistically model real-life environments. However, the neural mechanisms by which Virtual Reality might stimulate attentional functions in a more ecologically valid way than conventional training methods are still mostly unstudied. The objective of the present study was to examine the effects of different forms of binocular presentation (Virtual Reality-characteristic stereoscopic "3D" vs. monoscopic "2D") on neural processing during a visual attention task.

Methodology: Thirty-two healthy participants performed a visual attention task in an immersive virtual environment that was displayed via MR-compatible video goggles in an MRI scanner. The paradigm altered between trials that required active engagement with the task and mere observation trials. Furthermore, the form of binocular presentation switched between monoscopic and stereoscopic presentation.

Results: Analyses yielded evidence for increased activation in the Dorsal Attention Network (Figure A) when engaging in the attention task as well as elevated activation in stereoscopic compared to monoscopic trials in the tertiary visual cortex area V3A (Figure B). An additional ROI analysis of area V3A revealed significantly lower attentional engagement costs in stereoscopic compared to monoscopic conditions (Figure C).

Conclusion: The results indicate that stereoscopic 3D presentation led to lower neurophysiological costs in the extrastriate cortex when engaging in the attention task. This suggests that Virtual Reality could facilitate the deployment of visual attention from a metabolic perspective. Further research is needed to examine the clinical implications. Considering V3A's critical position as the origin point of multiple visuomotor systems, it seems plausible that ecological validity (in this case stereoscopy) could lead to the recruitment of more action-oriented networks downstream of V3A.

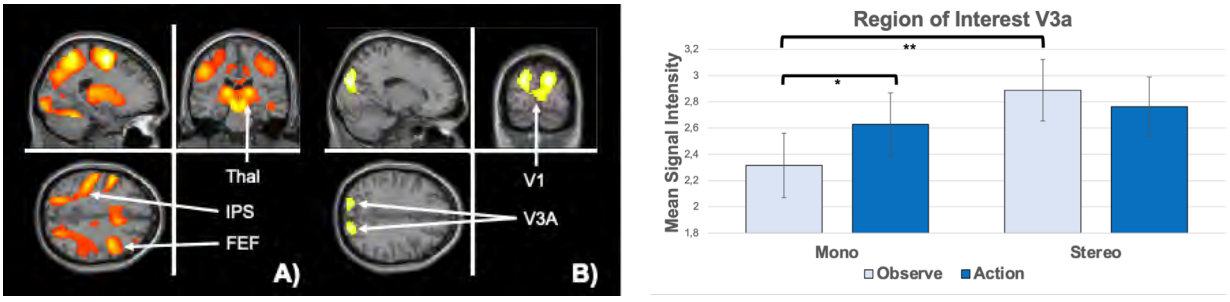

Figure: A) Activation of Dorsal Attention Network as a consequence of engagement with the visual attention task B) Increased activity in extrastriate area V3A in stereoscopic conditions. C) Lower metabolic

P1-12

FEASIBILITY, ACCEPTABILITY, AND USABILITY OF A TELE-REHABILITATION COMBINING IMMERSIVE VIRTUAL REALITY EXERCISES AND THERAPEUTIC EDUCATION FOR PERSISTENT NON-SPECIFIC NECK PAIN: A MIXED-METHODS PILOT STUDY

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Background: Current best clinical practice guidelines recommend the use of therapeutic education and exercises in the management of persistent neck pain. Immersive virtual reality (VR), an innovative means of rehabilitation using serious games to perform exercises, has been studied for several years as an intervention for persistent neck pain (at home or in clinic) and seems to be at least as effective as conventional interventions. Since the COVID-19 pandemic, the use of tele-rehabilitation has increased, with good results in the management of musculoskeletal disorders. However, no study to date has investigated multimodal tele-rehabilitation, combining both specific exercises in immersive VR and therapeutic education, in people with persistent non-specific neck pain (NSNP). The primary objective is to determine the feasibility, acceptability, and usability of tele-rehabilitation combining immersive VR exercises and therapeutic education in people with persistent NSNP. Secondary objectives are to investigate changes in clinical outcomes (range of motion, pain intensity, neck disability, illness perceptions, kinesiophobia, impression of change) and to explore the subjects' experience of the intervention.

Methodology: The intervention is a 6-week multimodal tele-rehabilitation consisting of therapeutic education and immersive VR exercises using serious games (5 immersive VR sessions and 1 teleconsultation session with a physiotherapist per week). Immersive VR exercises target relaxation, mobility, control, and speed of cervical movements, using the Pico G2 4K headset and the Corpus VR Personal app (InMotion VR, the Netherlands). In addition, participants receive several brochures to read on their own (covering the general principles of pain, the persistence of pain, and tips for managing persistent NSNP). Participants are assessed at the start and at the end of the intervention, using questionnaires (quantitative outcomes) and semi-structured one-on-one interviews (qualitative outcomes). Given the design of this study, we estimate that 10 to 15 participants need to be recruited.

Results: Recruitment began in November 2023. Currently, 4 participants have been included in the study (2 of them completed it). So far, the quantitative and qualitative results are positive, but we can't yet draw any conclusions due to the limited number of participants. We estimate that we will be able to recruit at least 10 subjects by the time of the congress, which will enable us to present the near-final results of the study.

Conclusion: Study findings will provide evidence concerning the feasibility, acceptability, and usability of multimodal tele-rehabilitation for persistent NSNP using immersive VR. The qualitative part of this study will provide a better understanding of patients' perspectives on this new type of rehabilitation and could help to individualize treatments by considering the patient's point of view, so that intervention is more patient-centered.

Keywords: Immersive virtual reality; Neck pain; Tele-rehabilitation; Qualitative; Quantitative

P1-13

3D VIRTUAL REALITY PRISM ADAPTATION SIMULATION SYSTEM FOR HEMISPATIAL NEGLECT

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Objectives: Hemispatial neglect syndrome is a neuropsychological condition, that fails to report, respond, or orient to external stimulation located contralateral to a brain lesion when the failure cannot be attributed to a primary sensory or motor deficit(Heilman, Watson, & Valenstein, 1985). Prism adaptation training was effective for the treatment of hemispatial neglect(Rossetti, 1998: Pisella, 2006). We developed a 3D VR prism adaptation simulation system. The purpose of the study was to evaluate the effects of the VR training with the simulation system for hemispatial neglect rehabilitation.

Materials and methods: The 3D VR prism adaptation simulation system was developed to implement the prism adaptation training. Leap motion was used for hand motion tracking. Oculus Rift dk2 was used for prism simulation immersive virtual reality presentation to the subject. The 3D VR prism training program consisted of 3 sessions which repeated 10 times over 2 weeks. In the first session, the subjects were instructed to move their virtual hand straight to a midline target in the VR. During the training, the hand path tracking was not displayed except for the initial starting portion and the ending portion, which simulated the prism glass training environment. The first session finished when the subjects succeeded in hitting the target 20 times continuously. In the second session, the virtual hand path was programmed to move 10° deviated rightwards from the original path which was blinded to the subject, simulating the prism glass applied condition. The subjects missed the target to the right side initially. But after several trials of targeting error, the subject adapted to the deviation and could hit the target correctly. After adaptation to the deviation condition, the third session started, in which the hand path deviation was eliminated blinded to the subject. The subjects showed left side target missing initially, which was similar to 'the after-effect' of prism glass training. Neglect tests (line bisection test, Albert's test, and star cancellation test) were performed before, one week, and two weeks after the interventions to evaluate the effect of 3D VR training.

Results: Ten subjects(M:F=7:3) with hemispatial neglect due to the right brain lesion were recruited. Line bisection test scores were improved from 48.51%(before) to 57.31%(1 week) and 64.76%(2 weeks)($p < 0.01$). Albert's test score were improved from 62.75%(before) to 81.50%(1 week) and 92.50%(2 weeks)($p < 0.01$). Star cancellation test scores were changed from 41.25%(before) to 53.04%(1 week) and 59.82%(2 week)($p < 0.01$).

Conclusions: All neglect test scores became improved after the 3D virtual reality prism adaptation simulation training. Hemispatial neglect improved significantly using the 3D VR prism adaptation simulation program.

Keywords: Hemispatial Neglect, Rehabilitation, Virtual Reality, Prism

P1-14

BARRIERS FOR THE ADOPTION OF SERIOUS GAMES IN PHYSICAL REHABILITATION THERAPY

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Background: Rehabilitation focuses on repetitive exercises for optimal results. Immediate improvement is rare, impacting patient motivation and adherence. To address this, serious games (SGs) are integrated in rehabilitation to incentivize correct and regular exercise execution. SGs offer engaging, pleasing experiences and/or incorporate gamification elements like points and badges to improve motivation.
Yet, despite collaborative design with therapists, many SGs face inconsistent usage beyond the initial sessions. The reason for this is unclear and results in the underutilization of potentially more efficient standard of care options, and diminishes the marketability of the SGs for the developers. Thus, we set out to investigate the inconsistent use of SGs in rehabilitation and define guidelines to tackle this.

Methodology: We conducted two 2-hour focus groups with physio/occupational therapists. The first group (5 therapists) had minimal SGs experience, while the second (8 therapists) had 6 therapists with experience and 2 with no experience but who wanted to use SGs. We also conducted 3 semi-structured interviews, 40 minutes each, with representatives from rehabilitation SG development companies. Sessions were audio and video-recorded, transcribed, and data was clustered using the NASSS framework as a rough guideline.
We first identified enablers/barriers for the adoption of SGs in rehabilitation. From this, one guideline focusing on SG design and one focusing on organizational SG implementation were defined.
A small 4-day game jam was organized to assess the SG design guidelines in terms of clarity, applicability, and usefulness. Two groups of students (11 total) participated in creating a rehabilitation game for dynamic balance while using the guidelines, as well as 2 provided personas and a video library of rehabilitation exercises.

Results: The design guidelines include technical and game design challenges from the perspective of therapists (difficult setup, limited personalization) and game developers (alignment between tasks & activities of daily living, no one size fits all). The implementation guidelines cover organizational problems for both therapists and developers (lack of availability/time, limited technical support), in addition to business- related barriers (lack of clear business case, focus on publications).
We were not able to evaluate all the SG design guidelines due to the speedy nature of game jams, particularly those involving therapists and patients. Some technical guidelines proved useful, but some were too complex to program in 4 days. The implementation guidelines were discussed with the partner medical institutions and refined based on their feedback.

Conclusion: The first iteration of the guidelines provides a solid foundation to encourage discussions among stakeholders about designing SGs that are beneficial and usable for patients and therapists, and a valuable investment for both companies and medical institutions.

Keywords: Serious games, rehabilitation, design guidelines

P1-15

STUDYING THE EFFECTS OF TASK-INTRINSIC STRESS ON COGNITIVE-MOTOR PERFORMANCE USING VIRTUAL REALITY

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Background: Task-intrinsic stress, derived from the inherent demands of a task, simulates real-life challenges and can be crucial for rehabilitation strategies. This study investigates the effects of this stress, induced by increasingly complex virtual reality (VR) based tasks, on cognitive and motor functions, utilizing physiological and performance metrics to gauge stress responses.

Methodology: Ten participants (20 ± 36 years old, 7 females) completed a VR-based Color Trail Test (VR-CTT) with increasing difficulty levels. Heart rate variability (HRV) was measured to assess physiological stress responses, while cognitive performance was evaluated through completion times of the VR-CTT tasks. Motor performance was analyzed by measuring head-hand (HH) temporal lag (i.e., one of the outcomes of cross correlation function), which serves as a proxy for motor synchronization between task related movements of different body organs (head and hand).

Results: Preliminary analysis indicate that cognitive and motor performances are significantly associated with the subjective difficulty of tasks. Within the cognitive domain, HRV exhibited an inverted-U relationship with task difficulty, suggesting optimal engagement at moderate stress levels, while extremely high or low stress levels impaired performance. In the motor domain, there was a general decrease in head-hand synchrony, as reflected by increased HH timelag with more complex tasks. Additionally, a notable finding was that a negative HRV shift correlated with shorter HH lags in the most demanding trails, suggesting that maladaptive stress responses were associated with better synchronization between head and hand movements.

Conclusion: The study highlights VR's value as a dynamic tool for simulating real-world tasks and stresses in a controlled environment. The variability observed in HH lag and HRV responses emphasizes the potential of using VR to tailor rehabilitation and training programs to individual stress profiles and motor coordination challenges, thereby enhancing the ecological validity and therapeutic effectiveness of interventions.

Keywords: Virtual Reality, Cognitive-Motor Performance, Task-Intrinsic Stress, Head-Hand Synchrony, Cognitive Load, Rehabilitation

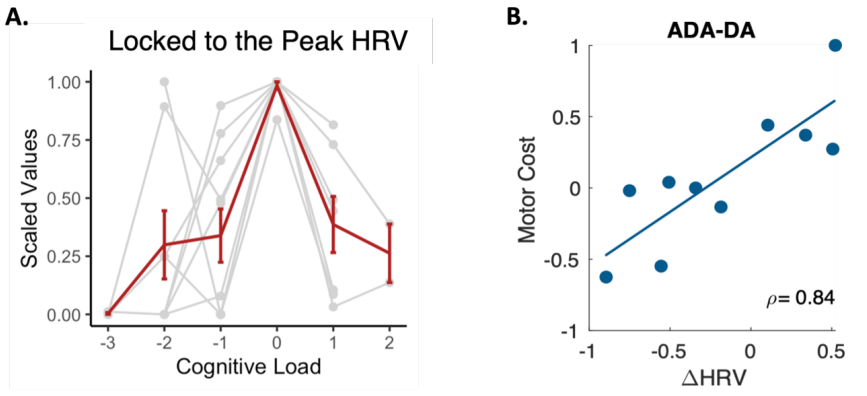

Fig. 1: Cognitive load and performance metrics; **A.** HRV patterns are aligned to each participant's peak HRV, with the peak labeled as 0, revealing an overall inverted-U-shaped response to cognitive load. Note: To standardize the response curves, the original four cognitive levels were spaced on a six-level scale on the x-axis. **B.** The correlation between HRV shift and changes in head-hand lag within the most challenging Trails (Arithmetic Divided Attention task; ADA - Divided Attention task ; DA).

P1-16

ENHANCING VISUAL AND ATTENTIONAL REHABILITATION WITH XR AND EYE TRACKING: INNOVATIONS FROM THE XREHAB PROJECT

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Background: Visual and attentional disorders are common in the general population and have been reported in a large number of conditions including stroke, dementia, schizophrenia, depression, ADHD, and autism. Visual and attentional disorders can significantly impact daily functioning and quality of life. Extended Reality combined with eye tracking allows for precise monitoring and analysis of eye movements. As part of the XRehab project in Flanders, in which we co-created use cases with rehabilitation professionals and XR companies, we developed three prototypes to demonstrate different ways in which eye tracking can have an added value for clinical use when combined with XR.

Methodology: The first prototype is based on standard Goldmann perimetry. Eye tracking is adopted for central fixation control and detection of peripheral stimuli on a dark background can be assessed or trained. Reaction times and missed targets are recorded and visualized according to location. Hardware consists of the Quest Pro with integrated eye tracking.

The second prototype shows the possibility of uploading a 360 degrees picture/video in XR and eye tracking is adopted to demonstrate real-time eye movements in this environment. It can also present a heatmap of the eye movements. This prototype can be used to train spontaneous visual exploration in patients with attention disorders or visual disorders. Hardware consists of the Vive with integrated eye tracking and Tobii software.
The third prototype is a 360 degrees selective attention task where eye tracking is adopted as a response medium (gaze interaction, no motor response required). Subjects are required to detect targets between distractors in a forest. Difficulty levels and location of the targets can be adapted based on the performance of the subject. Reaction times and missed targets are recorded according to location. Hardware consists of the Quest Pro with integrated eye tracking.

Results: Two prototypes will be demonstrated on-site and can be tried out by the public. User experience research and data examples from therapists and patients will be collected from February to May 2024 and will also be shown.

Conclusion: XR and eye tracking can be an interesting combination to train visual and attentional skills and has a clear added value to standard therapy. Eye tracking can be used for eye fixation control, monitoring real-time eye movements, creating heatmaps, and gaze interaction. In addition, XR allows exercises to be adapted to the subject's unique profile. This approach makes exercises more effective and can boost subject's motivation and participation in the rehabilitation process.

P1-17

MINDFLOW MASTERY: VIRTUAL VOYAGE TO TEEN TRANQUILITY - ELEVATING EMOTIONAL WELLNESS WITH E-LEARNING AND VR ADVENTURES

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Background: Adolescence, a pivotal phase characterized by physical, emotional, and social changes, poses unique mental health challenges for youth with neurodevelopmental disabilities (NDDs, e.g., cerebral palsy). The complexities of NDDs amplify emotional regulation struggles during this vulnerable period, affecting overall mental well-being, with cumulative challenges leading to heightened stress, anxiety, and depressive symptoms. Early intervention and tailored mental health support are crucial, yet recent research underscores significant deficiencies in available services for children with NDDs, particularly adolescents, revealing limited accessibility. Additionally, the current landscape of mental health programs for adolescents lacks innovation, highlighting the need for evolving approaches that align with the dynamic interests of adolescents, while ensuring engagement and effectiveness in addressing mental health concerns. An overarching objective is to enhance emotional regulation and promote relaxation in adolescents with NDDs using innovative strategies. To that effect, specific objectives include to 1) Co-design the MINDFLOW MASTERY program to encompass online learning modules and virtual reality (VR) sessions for adolescents with NDDs; and 2) Estimate the usability of, satisfaction with, and the preliminary impact of this program on mental health outcomes among adolescents with NDDs.

Methods: The proposal is embedded in an integrative knowledge translation approach, where the engagement of clinical- and youth-partners as key stakeholders is central to the co-design of the program. In a pilot pre-post experimental study design, we plan to recruit adolescents (n=25) to engage in the MINDFLOW MASTERY program over a 4-week period. It will consist of completing short online educational modules about emotional regulation (n=4, 1 module/week) along with one 30-min VR relaxation session (using Oculus Quest) offered once/week for 4 weeks. Outcomes will be measured pre- and post-program and will include the Revised Children's Anxiety and Depression Scale and the Emotion Regulation Questionnaire for Children and Adolescents. Post-program measures will include usability (System Usability Scale), satisfaction, perceived strengths/challenges, and impact (semi-structured interviews). Descriptive and inferential statistics (in IBM SPSS Statistics) and a hybrid inductive/deductive thematic analysis (in NVivo International QRS) will be used to analyse quantitative and qualitative data, respectively.

Contributions: This proposal aims to address gaps in mental health services for adolescents with NDDs by co-designing an innovative program combining online learning modules and VR, providing a tailored and holistic approach to enhance emotional regulation and promote relaxation, ultimately filling a significant void in effective mental health interventions for this specific demographic.
Keywords: emotional regulation, virtual reality, relaxation, online coaching, youth, developmental disability

P1-18

FEASIBILITY OF IMPLEMENTING VIRTUAL REALITY IN A COMMUNITY ORGANIZATION

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Background: Physical activity is essential for maintaining overall health and well-being. However, barriers to accessibility persist, including the lack of accessible adapted facilities and equipment. Although non-profit organizations can provide accessible options, limited resources make it difficult to accommodate individual goals and limitations. The burgeoning virtual reality (VR) market, valued at approximately $60 billion in 2022, presents an innovative avenue to overcome these barriers and to improve the practice of adapted physical activity because VR can offer immersive, safe, and customizable environments for users. Our study aims to understand the feasibility of implementing VR in a community organization for individuals with physical disabilities to promote the practice of physical activity.

Methodology: Mixed-methods longitudinal exploratory design in collaboration with a VR company (OVA) a non-profit organization (Adaptavie), and a patient partner. Individuals participated in various services within the community organization, where VR gaming sessions (included both custom-created and commercial games) were used. Feasibility was assessed using the 8 criteria established by Bowen (2009). These criteria were studied throughout the sessions, using videos to assess the level of engagement (PRIME-O) (practicality, expansion) and questionnaires to report side effects (SSQ) (limited efficacy) and appreciation (Likert Scale). At the end of the intervention period, acceptability was assessed using a questionnaire (F-SUS). Semi-structured interviews were also conducted to assess all the feasibility criteria (demand, implementation, adaptation, integration). Qualitative data was analyzed using a mix method (inductive and deductive), while quantitative data was analyzed using means and standard deviations.

Results: A total of 12 adults with physical disabilities and 7 interventionists participated in multiple VR gaming sessions (mean = 7.3 sessions). They all enjoyed the experience and expressed a high level of appreciation with minimal side effects (Table 1). Adults with physical disabilities said they felt more motivated and involved in physical activity and were able to work on their physical and cognitive skills tailored to their abilities. They also appreciated the social interaction and immersive nature of the experience. Interventionists highlighted these results. Recommendations and directions for future utilization were proposed, indicating enthusiasm for continued exploration of VR interventions.

Conclusion: The findings from the interviews further supported the feasibility of incorporating VR gaming sessions into community organizations. Results underscore the importance of ongoing development and integration of VR-based interventions to promote a healthy and active lifestyle. Subsequent research in this program will focus on the sustainability of VR integration through the creation of a Living Lab in the community organization.
Keywords: Feasibility, Virtual Reality, Adapted Physical Activity, Collaboration, Sustainability

	F-SUS	SSQ		Likert Scale Appreciation
		Nausea Symptoms	Oculomotor Symptoms	
Mean	88/100	0.07	0.3	9.37/10
Standard Deviation	9.84	0.11	0.27	0.78

Table 1.

P1-19

TOWARDS NONVERBAL MEASUREMENTS OF EMBODIMENT OF REAL-WORLD ORTHOSES USING VIRTUAL LIMBS: A STUDY PROTOCOL

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Background: To improve the quality of life of their users, assistance systems for movement, such as orthoses, rely on the successful integration of the system into the users' body representation, including body scheme. The perceived embodiment of orthoses shows promise in predicting this integration into everyday motor practice, primarily quantified through questionnaires. However, identifying physiological and proprioceptive correlates of orthosis embodiment could lead to a more comprehensive understanding of the integration.
The integration of a device in one's body representation can be assessed by the embodiment of an avatar wearing an orthosis [1] in Virtual Reality (VR), one form of full-body illusion. We developed a VR physiological setup evaluating avatar embodiment. The study aims to determine whether perceived embodiment in VR can be estimated from physiological correlates and if this method is a reliable approach for measuring and potentially forecasting the integration level of an assistive device into the body scheme.

Methodology: At the Clinic for Orthopedics of Heidelberg University Hospital, we assess locomotion features of patients with drop foot before and after a 3-month period of wearing an orthosis. Subsequently, we will conduct physiological and proprioceptive assessments using our VR-based setup to evaluate orthosis integration. It includes a MP160 system, with skin temperature and skin conductance amplifiers from BIOPAC and an HTC Vive Pro Eye. The QuickVR library, designed by collaborating colleagues at University of Barcelona, allows the embodiment of a full-size avatar wearing an orthosis. We will evaluate the responses to visuotactile stimulations, threatening events, and proprioceptive tasks.

Anticipated results: A robust orthosis integration is expected to manifest by a decrease in the whole-body skin temperature, result of a 'disownership' of the real body parts in favor of the ownership illusion [2]. After visuotactile stimulations (Fig. 1a), a successful embodiment of a virtual limb will also correlate with physiological threat reactions. Higher skin conductance responses are expected when participants perceive the virtual threat as targeting their real limb (Fig. 1b).

Low integration is suggested by a restricted control of the avatar's movements, reflecting poor adjustment abilities in aligning the "wrongly tracked" virtual limb to its target position (Fig. 1c). This is accompanied by a decline in proprioceptive accuracy and space-scanning abilities and increased focus on walking surfaces.
Conclusion: Full-body illusions alter bodily self-consciousness and instigate widespread physiological changes. Perceived embodiment is a promising concept to assess an assistive device's integration in the body scheme. Conducting a comparative analysis between physiological metrics and self-reports would also be valuable to determine whether these methods differentially predict the adjustment to a device.
Keywords: Embodiment; assistance systems integration; skin temperature; skin conductance; proprioception

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Acknowledgements: This work is funded by the Deutsche Forschungsgemeinschaft (RTG LokoAssist – Seamless integration of assistance systems for natural locomotion of humans – Project D2).

Figure 1: Implemented tasks with QuickVR in Unity.

P1-20

EVALUATING VIRTUAL REALITY HIGH-INTENSITY INTERVAL TRAINING IN HEALTHY YOUNG ADULTS: PHYSIOLOGICAL AND PSYCHOLOGICAL IMPACTS FROM A PRELIMINARY PILOT RANDOMISED CONTROLLED TRIAL

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[1] *Teesside University*

Background: With the advent of affordable, fully immersive technologies, Virtual Reality (VR) has emerged as a novel medium for delivering exercise interventions. This study assesses the feasibility and efficacy of VR-based High-Intensity Interval Training (HIIT) compared to traditional HIIT on physiological and psychological outcomes in physically active healthy young adults. As a relatively new technology, there are few studies exploring the implications and effectiveness of VR for physical activity, making this research critical in understanding its potential for health promotion.

Methodology: Employing a parallel-design pilot randomised controlled trial, we assigned ten healthy participants (3 females, 7 males; mean age = 24.0, SD = 2.7) to either a single VR HIIT session delivered using the Facebook Oculus Quest 2 and FitXR game or a traditional, mirror-matched HIIT session, both lasting approximately 15 minutes. We measured heart rate parameters, Rating of Perceived Exertion (RPE), and flow experience using the Use of Technology and the Flow State Scale questionnaire to gauge the interventions' physiological and psychological impacts.

Results: Our findings indicate no significant difference in heart rate parameters between the VR and non-VR groups, demonstrating comparable exercise intensities were achieved between both interventions that were found to be of sufficient intensity for health benefits. However, the VR group reported significantly lower RPE scores ($p < 0.001$, $d = -3.72$; 95% CI: -3.1 to -1.3), suggesting a reduced perception of effort compared to the non-VR group despite comparable intensities. Furthermore, the VR group experienced a significantly higher post-intervention flow state in the subscale Unambiguous Feedback ($p = 0.04$, $d = 1.58$; 95% CI: 0.1 to 2.0), while the subscale Transformation of Time was found to be approaching statistical significance ($p = 0.07$, $d = 1.37$; 95% CI: -0.1 to 2.9), highlighting a more engaging and motivating exercise experience and a reduced perception of time during gameplay.

Conclusion: This pilot study provides preliminary evidence that VR HIIT can serve as an effective alternative to traditional HIIT, enhancing exercise motivation through a high-flow experience, clear immediate feedback (subscale: Unambiguous Feedback), and perhaps an altered perception of time (subscale: Transformation of Time). The results underscore the potential of immersive VR in promoting physical activity, warranting further investigation with larger samples and diverse populations to explore broader physiological and psychological impacts.

Key words: Virtual Reality, High-Intensity Interval Training, Flow Experience, Rating of Perceived Exertion, Randomised Controlled Trial, Oculus Quest 2

P1-21

DEVELOPMENT OF A VIRTUAL CLINIC FOR CHILDREN WITH RARE DISEASES

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[1]CFD Research

Background: Children living with rare diseases face constant challenges, including pain, reduced mobility, and difficulty performing activities of daily living. These children often require regular physical therapy to maintain function and slow symptom progression. Patients are also burdened with the frequent need to travel long distances to receive care from geographically scattered specialists. Virtual Reality (VR) has the potential to alleviate these issues providing effective remote care. To address the issues of providing prolonged care to individuals with rare diseases, we are developing a comprehensive VR clinic which includes a platform for telehealth visits with clinical specialists, continuous health monitoring using connected sensors, and gamified rehabilitation. We believe this system will allow for high-quality, long-term care without the need to regularly travel.

Methodology: The Virtual Clinic enables at-home rehabilitation, remote patient monitoring, and telehealth visits. Specifically, the system improves at-home rehab by turning standard physical therapy exercises and assessments into fun, engaging games, increasing the likelihood of compliance. Through the use of wireless wearable sensors, the system is able to track key health metrics over time allowing better insight into patient's status. Data is stored in a secure database and accessible to clinicians through a web portal. Not only can clinicians view trends in the data, machine learning algorithms help identify correlations, further informing care. Telehealth sessions also happen within the VR environment where the clinician can display data from the web portal and discuss results with the patient. The clinician is also able to adjust the exercise prescription remotely on the web portal.

Results: Through regular discussions with key stakeholders, including parents of children with rare diseases, clinicians who diagnose rare diseases, pediatricians, and physical therapists, we have been able to incorporate their feedback to ensure the system will meet their needs and provide the capabilities that would be most impactful to patient care.

Conclusion: Our system combines at-home rehab gaming, sensor-based continuous patient monitoring, data capture, processing, and visualization, and telehealth consultation into a single solution. This reduces complexity by removing the need for multiple systems. Additionally, the unified system provides better insight into the patient's status and enables more effective communication and remote care. While this system is being developed for children with rare diseases, it can easily be adapted to work for a broad range of patient populations that require effective at-home care.

Acknowledgement: This project has been funded in whole or in part with Federal funds from the National Center for Advancing Translational Sciences, National Institutes of Health, Department of Health and Human Services, under Contract No. 75N95023C00009.

P1-22

DYNAMIC ASSESSMENT OF EVERYDAY COMMUNICATION USING VIRTUAL REALITY: PROOF OF CONCEPT FOR PERSONS WITH APHASIA (DCOM-VR)

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[1]Radboud University, [2]HU University of Applied Sciences Utrecht, [3]Siza, [4]The Simulation Crew

Background: People with aphasia (PWA) experience language impairments due to brain damage such as stroke. Daily (functional) communication is already difficult because of the language impairment, but also because of additional cognitive demands such as time pressure and the distractions such as noise. Assessment of everyday communication, however, remains a challenge. Mainstream pen-and-paper based instruments do not capture the complex cognitive demands that are present in the real world, which means they are not representative of day-to-day communication.

The goal of this project is to develop a (proof-of concept version of) a functional communication test for PWA, using virtual reality (VR). VR makes it possible to simulate realistic communicative interactions between a person and a computer-generated avatar, including both verbal and nonverbal behaviour. It also allows manipulation of various factors (i.e., background noise) that may increase communicative complexity and assess their impact. What is more, non-linguistic cognitive problems (particularly executive control difficulties) can make it difficult for PWA to imagine being in a communicative situation and to pretend having a conversation. As VR may help PWA to put themselves in a communicative situation, it is expected that the validity of the VR-based communication test will be increased in comparison to a pen-and-paper based version.

Methodology: This 2-year project will move through four key stages, based on the design thinking process. The main aim of phase 1 Understand is to fully understand the needs of PWA and speech and language therapists (SLTs), current practices and existing problems in assessment of functional communication. A literature review, focus-groups and shadowing sessions are organised to achieve this. In phase 2 Explore, co-design workshops with stakeholder representatives will be utilised to generate and prioritise ideas for improvement of assessment practices, generally and specifically for VR. Phase 3 Materialise will encompass the technical development of the VR-based instrument. This will be done through a process of iterative design, whereby the end-users (PWA and SLTs) will be consulted at different intermediary stages of development. Phase 4 Engagement and sustainability will be focused on engagement and knowledge-sharing with the wider community of targeted stakeholders.

Results and conclusions: This is an ongoing project, currently in the second phase. The results from the first two phases, leading to prioritised ideas for development of the POC version of the VR-based communication test, will be discussed.

Keywords: Aphasia, Virtual Reality (VR), everyday communication, (dynamic) language assessment, aphasia test
Acknowledgements: This study is supported by the Dutch Research Council (NWO) under Grant NWA.1418.22.025

P1-23

AT-HOME VR TREATMENT FOR PATIENTS WITH CHRONIC MUSCULOSKELETAL PAIN: A CLUSTER RANDOMIZED CONTROLLED TRIAL

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Background: Chronic musculoskeletal pain (CMP) is prevalent in approximately 20% of adults. CMP often negatively influences patients' quality of life, daily functioning and occupational activities. Virtual reality (VR) has been introduced as (adjunct) intervention for patients with CMP. However, still is yet unknown about the effectiveness of VR for CMP. The aim of this study was to examine the effectiveness of a VR intervention in patients with CMP that were on the waiting list to receive pain treatment, compared to waiting list patients that did not receive treatment during this period.

Methodology: This study employed a two-arm, cluster-randomized crossover design in four healthcare organizations. The used VR application, Reducept, offers pain education and pain management techniques. This home-based, stand-alone, immersive VR intervention was used daily for four weeks in the intervention group. The control group received standard care (no treatment). Primary outcome measure for this study was health-related quality of life, secondary outcome measures included various pain-related variables (e.g. pain self-efficacy and acceptance). All outcome variables were measured before and after four weeks. Both within and between group analyses will be conducted to evaluate the effect of this intervention.

Results: Ethical approval was obtained from both the University of Twente (identifier: 230405) and local ethics committees of the four participating healthcare organizations (i.e. Roessingh, Revalidatie Friesland, ZGT Nocepta and Deventer hospital). Recruitment of patients is currently in progress (n=34) and first results are expected before June 2024 to be presented.

Conclusion: The results of this study are expected to provide insights in the effectiveness of VR in patients with CMP that are on a waiting list to receive pain treatment.

P1-24

THE INTERACTION OF AUTOMATIC AND VOLITIONAL MOTOR TASKS DURING POSTURAL CONTROL AND COGNITIVE CHALLENGES IN VIRTUAL REALITY

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Background: The impact of dual-task effects on postural control is still an open question in the literature. Postural control is generally described as an automatic motor control process, which suggests that balance should not be affected by secondary non-motor tasks. However, many studies have shown dual-task costs of cognitive interference during balance. The purpose of this study is to manipulate the levels and types of cognitive and motor challenge. This can help identify when balance control and cognition tap into common attentional and/or neural resources and help to better understand the cognitive penetrability of postural, reaching, and fine-motor processes.
Methods: Healthy adult subjects (n=8) stood on a motorized sway-referenced (SR) force plate with SR-gain set to 0 (fixed surface), +1, +2, or -2, while wearing a VR head-mounted display. Four levels of cognitive challenge were tested: no-task, math (serial 7 subtraction), Simon task with thumb-controlled joystick (thumbstick) or by manually pointing. The Simon task involved displaying an arrow pointing one of four directions in one of four quadrants on the VR screen and subjects had to indicate the direction the arrow was pointing – not the quadrant the arrow was in. Subjects first completed 2 practice trials for each of the cognitive tasks while seated, the second of which was used as a baseline, and then completed the other conditions in a random order.

Results: Center of pressure (CoP) sway increased significantly during the SR+2 conditions compared to the fixed surface conditions ($F_{3,21}=74.3$, $p<0.001$). CoP sway during the thumbstick conditions was similar to sway during the no-task conditions, but significantly increased during the pointing conditions ($F_{3,21}=14.6$, $p=0.002$). A non-significant trend in COP ($F_{3,21}=4.27$, $p=0.078$) was found in the math versus no cognitive task conditions when comparing the most challenging postural conditions (SR+2 and SR-2) to the easier ones (fixed and SR+1). There was a significant interaction of cognitive-motor and postural task ($F_{3,21}=5.64$, $p=0.02$); as difficulty of the postural task increased, the impact of the cognitive-motor task disproportionately increased. Accuracy in the cognitive tasks was unaffected by balance conditions.

Conclusion: The results showed cognitive-motor interactions were present, however, there was no significant cost to cognitive task performance as postural challenge increased. Specifically, the introduction of the cognitive-motor (pointing) task significantly affected balance. It appears that even under difficult postural conditions (SR+2), a simple cognitive task (math or thumbstick) bears no effect. It is only when combined with a more complex cognitive-motor (Simon pointing) task that postural stability is impacted. Together, these results provide a further understanding of cognitive and motor interactions during postural control and can serve to guide the development of effective dual-task training and treatment.

Keywords: Dual-task, Postural control, cognitive interference, Simon-effect

Acknowledgements: This study was funded, in part, by the Binational Science Foundation (BSF#2019222).

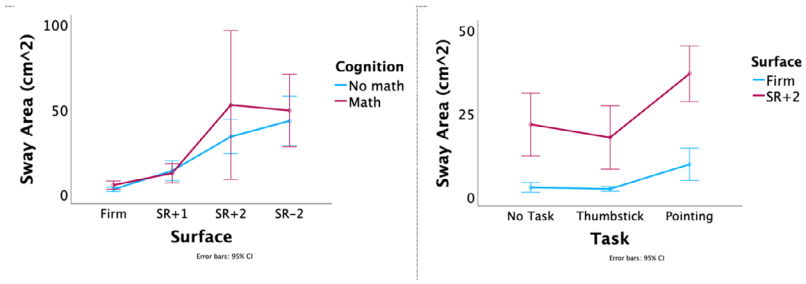

Fig 1. Left. COP showed increasing sway area from SR gain equals 0, +1, +2, -2. Also, the cognitive math task increased sway area in the most challenging balance conditions. Right. Sway area increased from SR gain equals 0 to +2. The cognitive-motor task increased the COP in the most challenging balance conditions.

P1-25

DEVELOPMENT OF VIRTUAL REALITY CASE SCENARIOS FOR PAIN SCIENCE CLINICAL REASONING EDUCATION

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Background: Pain is the main reason people attend physiotherapy. A structured approach to learning is essential to enhance physiotherapy students' development of clinical reasoning skills in pain management. At present, a lack of a framework in standardising physiotherapy education can potentially negatively impact patient care. The VR-Pain project aims to address these issues by developing VR clinical reasoning scenarios for acute and chronic pain that will support students learning in a standardised way mapping learning to best practice (Figure 1). This study focuses on developing VR case scenarios to identify gaps in pain science clinical reasoning skills development.

Methodology:
A two-stage process was undertaken:
(1)Curriculum review and requirements acquisition: All clinical partners mapped their pain science education, clinical reasoning skills development against the EFIC Pain Physiotherapy core curriculum[1].
(2)VR Scenario Development: To inform the development of the VR scenarios, a one-time workshop was conducted with stakeholders (5 people with pain and 5 students). Preliminary vignette scenario scripts (acute low back pain (LBP), acute post surgical pain, chronic LBP) were circulated to stakeholders for review and amendment.

Results:
(1)All three clinical partner sites completed the mapping matrix.
The timing of pain science teaching varied between programmes; in the two four-year programmes, it occurred in Years 1-4 (n=1) and Years 2-4 (n=1), while in the two-year programme, it spanned both years.
With regards to the EFIC curriculum, section 1 'Pain Science and Knowledge' and section 2 'Principles of assessment and measurement'– generally fully or partially taught in all programmes. In section 3 'Principles of treatment'– in general fully or partially taught in all programmes with one exception. Finally in section 4 'Pain Subgroups/Special Patient Populations' – certain topics were not taught in two of the three programmes.
(2)Based on the workshop, people living with pain placed importance on building their relationship and having good communication with their physiotherapist, for their physiotherapist to have adequate knowledge, and to adopt an holistic approach to their care.
Physiotherapy students considered key concepts to include being competent in being able to communicate complex issues. They also believed that the challenge of individualizing interventions for patients could be helped through practicing these skills and their application in a safe environment.

Conclusion: While there is overall consistency across programmes regarding core pain science topics, some variations were identified. Feedback from the stakeholders will be used to inform the VR scenarios. These case studies will enhance their clinical reasoning skills development in pain science to ultimately address patient care.

Keywords: Pain Science education, Clinical Reasoning skills development, virtual rehabilitation technology
[1]European Pain Federation EFIC Core pain science curriculum for undergraduate physiotherapy programmes (www.efic.org/education)

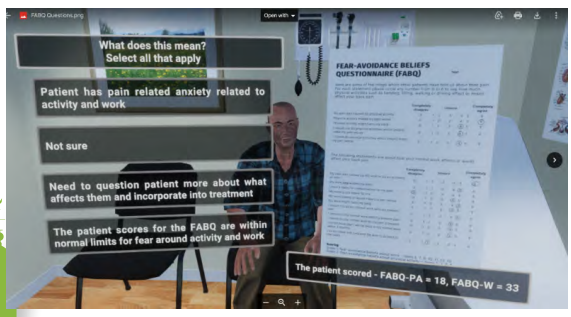

Figure 1. Sample image of VR clinical reasoning scenarios

P1-26

ENHANCED ECOLOGICAL VALIDITY OF ACOUSTIC VOICE ANALYSIS THROUGH VIRTUAL REALITY

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Background: Dysphonia is a widespread voice disorder among teachers, which is influenced by environmental factors. Instrumented voice assessments are accurate but are conducted in laboratories, potentially failing to capture real-world conditions that contribute to voice problems. Virtual reality can potentially improve the ecological validity of voice assessments by simulating virtual environments (VEs) that mirror real-world settings. Previous research has verified that VEs can yield acoustic characteristics of voice production comparable to those observed in actual classrooms.

This study compared the acoustic characteristics and perceived voice quality obtained from conventional assessments with those derived from a VE, varying classroom noise levels and the sense of presence experienced in the VEs.

Methodology: The study involved 30 university teachers, 17 of whom were female. On average, they had 41.0±8.3 years of age, 11.1±5.8 years of teaching experience and 12.5±6.4 hours of lectures per week.
Two 360º videos were created using a GoPro Max camera (4K@60 fps) depicting a classroom with 20 students who were quiet (40 dB SPL) or engaged in conversation (70 dB SPL). Videos were displayed using an Oculus Quest 2 headset with Soundcore Life Q30 headphones.
During the experiment, participants read the same text under three different conditions, conventional assessment, low-noise, and high-noise virtual classroom, while their voices were recorded. After each condition, participants assessed their voice fatigue using a 100-mm visual analogue scale and their sense of presence through the Slater-Usoh-Steed (SUS) questionnaire [range 1-7]. The experiment was conducted in a soundproof booth using an Audiotechnica AT2020 microphone and a Focusrite Scarlett 2i4 audio interface (@44.1kHz/16 bits). Acoustic analysis included the L1-L0 ratio, Alpha ratio, and 1/5-5/8 ratio. Audio analysis was performed using Praat software.

Results: All parameters examined in the conventional assessment showed significantly lower values compared to those in the VEs, except for self-perceived vocal fatigue, voice intensity, and breathiness, which were similar to those observed in the low-noise VE condition (Figure 1). Furthermore, all parameters measured in the VEs exhibited an increase corresponding to the intensity of noise. The scores in the SUS suggested a satisfactory sense of presence, for both the low noise VE (5.4 1.3) and the high noise VE (5.5 1.3).

Conclusion: Conventional laboratory-based assessment could not provide an accurate representation of vocal performance in real classrooms and only represent certain parameters of low-noise environments. The assessment in simulated VEs could improve the ecological validity of conventional methods.

Keywords: acoustic voice analysis, speech therapy, dysphonia, virtual reality, presence.

Acknowledgement: This study was supported by Conselleria d'Innovació, Universitats, Ciència i Societat Digital of Generalitat Valenciana (CIDEXG/2022/15) and by Ministerio de Ciencia e Innovación (PID2022-141498OA-I00).

POSTER SESSION 2
JUNE 28, 2024
12:30 - 13:45

P2-1 Validation of a simulated museum vr application for disability awareness

P2-2 Feasibility of virtual rehabilitation for children with sickle cell disease-related stroke in low-income countries: a pilot study in lubumbashi

P2-3 Error augmentation training in virtual reality for upper limb rehabilitation in stroke

P2-5 Extended reality in rehabilitation for patients with acquired brain injury: a scoping review

P2-6 Increased perception of reaching movements with combined and congruent visual and proprioceptive stimulation

P2-7 Cognitive load and game preferences in the gamification of neurorehabilitation-centric hand exercises in chronic stroke

P2-8 The autonomic nervous system response to visual-physical incongruent walking conditions measured by heart rate variability

P2-9 Feasibility of using immersive virtual reality in patients at an intensive care unit

P2-10 Cueing-assisted personalised augmented-reality exergaming for parkinson's rehabilitation: study protocol of a randomized crossover trial

P2-11 Developing an artifact to control motor execution variability in vr-based physical rehabilitation

P2-12 Co-design and development of immersive virtual reality serious games for upper limb rehabilitation

P2-13 Obstacle circumvention during omnidirectional treadmill walking in virtual reality

P2-14 Effectiveness of balance training post-stroke through exercises that combine motor and cognitive demands in individualized virtual reality-based environments

P2-15 Neurophysiological responses to immersive videos of relatives and strangers. Preliminary findings on healthy subjects and patients with disorders of consciousness

P2-16 Knowledge, practice, and acceptance of physiotherapists about the use of immersive virtual reality in clinical practice: an international online survey

P2-18 A study protocol into feasibility and acceptance of a virtual reality system that provides immersive experiences during robot assisted walking training (lokomat) for people with neurological conditions

P2-19 Virtual sedation as a substitute for pharmacological sedation: from vascular access to surgical procedures

P2-20 A novel xr use case for visualizing movement and performance in upper limb rehabilitation: innovations from the xrehab project

P2-21 Immersive virtual reality for psychosocial management and functional recovery in a patient with tibial plateau fracture: a case report

P2-22 Questionnaires for evaluating virtual reality: a scoping review

P2-23 Gait and balance assessments with hololens 2 and magic leap 2 in people with parkinson's disease: concurrent validity and testretest reliability

P2-24 A scoping review of frameworks evaluating digital health applications: scale-up4rehab project

P2-25 Cognitive flexibility training in virtual environment for patients with obsessive compulsive disorder

P2-26 Effects of virtual reality training on pain intensity and disability in patients with chronic low back or neck pain: a systematic review with meta-analysis

P2-1

VALIDATION OF A SIMULATED MUSEUM VR APPLICATION FOR DISABILITY AWARENESS

Philippe S. Archambault[1,2], Salman Nourbakhsh[1,2], Hélène Carbonneau[3]

[1]*McGill University,* [2]*Interdisciplinary Research Center in Rehabilitation,* [3]*Université du Québec à Trois-Rivières*

Introduction: People with disabilities encounter barriers to their participation in their daily activities. Some of these barriers are due to the social environment, i.e., attitudes and behaviour of other individuals with respect to persons with disabilities. There is a need to raise awareness about disability, in particular in employees of public and private establishments, who may encounter people with disabilities. It has been shown that role playing activities and discussions can be effective in raising awareness about the challenges experienced by people with disabilities. As such, virtual reality (VR) can be an effective tool for disability awareness. Therefore, two VR scenarios were developed through a co-design approach, involving individuals with disabilities and museum employees with expertise in accessibility. These scenarios explore social and physical barriers that a person with either a motor or visual impairment may experience while visiting a museum. The specific aim of this study was to evaluate the validity of our VR, disability awareness scenarios in terms of realism, potential usefulness and ease of use.

Methods: Five persons with disabilities (two with a visual impairment and three with a motor impairment) and seven museum employees were recruited for the study. Two VR scenarios were tested by the participants: a museum visitor with either a mobility impairment (wheelchair user) or a visual impairment, using the Oculus Quest 2 VR Headset. Following this, a semi-structured interview was conducted to gather information about the degree of realism, potential usefulness and overall ease of use of the VR disability awareness tool. Examples of questions included: "What characteristics in the virtual environment struck you?" and "How realistic do you think the tasks and activities of these scenarios are?" Interviews were recorded and transcribed verbatim, and then coded through a qualitative content analysis.

Results: Four main themes were identified. The first was 'Emotions', which included both negative (frustration, confusion) and positive (empathy) emotions experienced by participants in the VR scenarios. The second theme was 'Experience', or how the VR scenarios matched the participants' lived or professional experience. The third theme, 'Usefulness', described how the VR scenarios could be used as an 'icebreaker', to then teach appropriate interactions with persons with disabilities, and to increase awareness. In the fourth theme, 'Realism', participants explained how the VR scenarios presented a realistic rendition of accessibility/inaccessibility and of interactions with museum employees.

Conclusion: Our scenarios were seen as useful in describing social and physical barriers experienced by persons with disabilities. VR can be a valid tool to promote disability awareness among employees in a sociocultural setting to improve the inclusion of people with disabilities.

P2-2

FEASIBILITY OF VIRTUAL REHABILITATION FOR CHILDREN WITH SICKLE CELL DISEASE-RELATED STROKE IN LOW-INCOME COUNTRIES: A PILOT STUDY IN LUBUMBASHI

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Background: Sickle cell disease (SCD) is an inherited disorder causing red blood cells to assume a sickle-like shape, increasing the risk of cerebrovascular accidents, particularly in children. In low-income countries (LIC) like the Democratic Republic of the Congo (DRC), access to rehabilitation services for SCD-related strokes is severely limited due to a shortage of healthcare professionals. Consequently, stroke survivors often experience delayed, inadequate, and irregular rehabilitation, leading to long-term disabilities. It is however of the utmost importance to be able to provide rehabilitation services for these patients to avoid as much as possible long-term complication and to improve their functions and quality of life.

Methodology: We developed a rehabilitation center in Lubumbashi, DRC, using mostly serious games and virtual reality to try give the best rehabilitation services as possible taking into account the shortage of healthcare professionals. This feasibility study aimed to assess the viability of implementing virtual rehabilitation in LIC. After the installation of the lab a training program was organized locally to train the local professionals. The center utilized readily available technologies including Nintendo Wii, Switch, Microsoft Kinect, VR headset (Pico 3), and tablet-based cognitive training system. Five children and teenagers with SCD-related chronic stroke participated in one-on-one serious games rehabilitation sessions, ranging from 1 to 5 sessions per week over an 8-week period. The sessions were supervised by a trained physiotherapist in the newly developed center.

Results: In the pilot trial, patients exhibited a significant degree of compliance with the serious games rehabilitation program. Significantly, there were no instances of technical problems or negative occurrences reported, highlighting the dependability and security of the system. The application of serious games technology was crucial in promoting immersive and efficient rehabilitation sessions for the patients. This underscores the practicality of executing such a method in settings with low resources, as demonstrated by the specific circumstances of the DRC.

Conclusion: The integration of cost-effective and easily transportable serious gaming technologies into rehabilitation offers a hopeful solution for the shortage of healthcare personnel in LICs. This novel strategy provides a cost-efficient alternative with low training demands, potentially improving rehabilitation results for stroke survivors in these demanding environments. Through the utilization of technology, we can narrow the disparity in availability of high-quality healthcare services and enhance the well-being of patients undergoing stroke recovery in disadvantaged areas.

Key Words: Serious Games, Virtual Reality, Stroke, Children, Sickle Cell Disease

P2-3

ERROR AUGMENTATION TRAINING IN VIRTUAL REALITY FOR UPPER LIMB REHABILITATION IN STROKE

Caroline Rajda [1,2], Shelly Levy-Tzedek [3], Sigal Berman [3], Philippe Archambault [1,2], Mindy F. Levin [1,2]

[1]*McGill University,* [2]*Centre for Interdisciplinary Research in Rehabilitation,* [3]*Ben-Gurion University of the Negev*

Background: Stroke leads to long lasting deficits in upper limb (UL) sensorimotor function. Many people with UL hemiparesis have decreased active elbow extension leading to the use of compensatory movements to assist reaching. Evidence suggests that active elbow extension range can be increased by limiting elbow extension range during training to the specific active control range of each individual. This was done in this study using a novel implicit learning approach involving error augmentation (EA) feedback. The use of EA to improve endpoint performance of a reaching task has been reported in people with stroke but whether improvements were due to recovery of the active elbow control range or to the use of motor compensations was not addressed. Our objective was to compare effects of short-term reaching training with and without EA feedback in people with stroke. We hypothesized that people who trained with implicit EA feedback would increase their active elbow control range more than those who did not receive EA feedback and would be able to integrate the increased range into functional reaching activities.

Methodology: 25 people with chronic stroke practiced reaching with a custom virtual reality (VR) program. Participants practiced reaching in 3 – 30min sessions over 1wk either with or without EA feedback (150 trials/session). In the EA group, augmented feedback of elbow joint position in which the joint error was amplified by 30° was included to implicitly encourage the use of greater elbow extension. Prior to each training session, the horizontal arm workspace was calibrated to personalize the space in which reaching targets would appear so that only the elbow extension range that was not affected by excessive muscle coactivation was used during reaching. To evaluate the effect of training, UL, trunk, and endpoint kinematics were assessed as well as the index of performance, a measure of reaching success related to endpoint precision, speed, and task difficulty. The active reaching zone size was recorded by the VR program. Outcomes were assessed before, after, and 1 hour after training to evaluate motor improvement and learning during a standardized functional reaching task.

Results: Both groups improved joint and endpoint kinematics during reaching. People who trained with EA feedback tended to have a greater percent change in the active elbow control range, shown by changes in the elbow flexor tonic stretch reflex threshold, compared to those who trained without EA (EA: 10.97 29.59%; no EA: -3.34 15.91%). The EA feedback group also tended to have a greater percent change in the size of the active reaching zone compared to those who trained without EA, regardless of UL impairment severity (EA: 37.97 74.59%; no EA: 12.39 45.31%).

Conclusion: Results may inform the design of personalized training interventions based on the individual's specific UL motor impairment, as well as use of enhanced intrinsic feedback for UL recovery after stroke.
Keywords: motor learning, stroke, upper limb training, feedback, virtual rehabilitation

P2-5

EXTENDED REALITY IN REHABILITATION FOR PATIENTS WITH ACQUIRED BRAIN INJURY: A SCOPING REVIEW

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Background: Extended reality (XR) is promising for rehabilitation after acquired brain injury (ABI), given the benefits for recovery, hospital stay, costs and self-efficacy. However, XR for ABI is rarely implemented in rehabilitation practice. We conducted a scoping review to delineate current research on XR in ABI, focusing on user outcomes and experiences relevant for scaling up and further implementation research.

Methods: The Arksey and O'Malley framework and PRISMA-ScR reporting guideline was followed. Studies between 2010 and May 2022 screened from Pubmed, Embase, Cochrane, Cinahl, and IEEE and were imported in Rayyan. The eligibility criteria were patients with ABI, using XR or immersive Virtual Reality (VR), peer reviewed studies, and published in English. Full text analysis of all included studies filtered objectives and (user) outcomes of the XR interventions, factors considering scale up, and lessons learned using XR in rehabilitation. Three researchers selected relevant studies in three rounds based on title, abstract, and full text with a Fleiss' Kappa score for interrater reliability of 0.74 for titles and 0.40 for abstracts.

Results: 75 studies were included. 63 studies recruited stroke patients, while seven studies included participants with traumatic brain injury. VR was used in 70 studies and five studies applied augmented reality. XR environments, varied from real environments (n=23) to basic (n=23) and fictitious (n=18). Two main objectives of the XR applications could be distinguished: assessment and intervention, which were subsequently categorized into physical (n=41), cognitive (n=14), and multipurpose (n=3) interventions. Most of the included physical interventions focused on specific task improvement, reach and grasp, gait balance and walking, and motor function. Cognitive interventions focused on task sequence, practicing activities in daily living, improving visual field, and training neglect. Studies included patients based on the phase and symptoms of their neurological condition, with three studies focusing on mild impairments, one on mild to severe impairments, one on severe impairments, and one on severe stiffness. Furthermore, we found a large variety in used outcome measurements and to a lesser extent patient-reported outcomes.

Discussion: Our scoping review confirmed the potential of XR for ABI and refined potential effects. However, it did not answer the question how to incorporate XR in daily rehabilitation practice. Primary focus of studies were technical outcome and usability, but not applicability. Moreover, norms and values of a diverse and inclusive group of stakeholders were not addressed, whereas considering these are crucial for successful implementation. Based on this scoping review, we will conduct a series of studies according to the 'service model approach', to explore and substantiate elements that contribute to a sustainable implementation of XR in rehabilitation.

Keywords: Extended Reality, Rehabilitation, Acquired brain injury, Scoping review

P2-6

INCREASED PERCEPTION OF REACHING MOVEMENTS WITH COMBINED AND CONGRUENT VISUAL AND PROPRIOCEPTIVE STIMULATION

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Background: Sensory and perceptual information is crucial for optimizing motor learning and control through neural plasticity. How to enhance sensory inputs for the upper limb rehabilitation when active movement is impaired? Besides the often complex and costly solutions such as exoskeletons, proprioceptive and visual stimulations can be generated through muscle vibrations and virtual reality. Focal muscle vibration, a form of proprioceptive stimulation, allows modulation of movement perception. Processing of these proprioceptive and visual inputs by the brain is influenced by the amount of stimulation and the congruence of this information., i.e., whether they convey movement information in the same direction or not. However, they are rarely manipulated simultaneously, and the experimental outcomes without vision are predominantly allocated to proprioception without necessarily modulating it.

The primary objective of this study was to quantify and compare the perceptual effects of different visual and proprioceptive stimulations, applied individually and/or in combination, on the immobile upper limb in healthy adults.

Method: A convenience sample of 15 healthy adults was recruited for this quasi-experimental experiment. With the participant embodied in its avatar, virtual reality visually simulated reaching movements without actual movement from the participant, similarly for vibrations applied to the muscles of the elbow and shoulder. Movement perception was assessed using a scale from 0 to 10. The direction, speed, and amplitude of perceived movement were also quantified. The effects of different stimulations on perception were compared.

Results: The results showed that congruent stimulations are superior to incongruent stimulations for movement perception ($p < 0.001$). On average, participants rated movement perception at 5.1 (2.9)/10 for congruent stimulations and 3.5 (2.9)/10 for incongruent stimulations. Vibrations alone (no VR) resulted in movement perception as strong as congruent stimulations (VR + vibration) with an average rating of 5.1 (3.0) ($p => 0.42$). However, the variability of perceived direction of movements was higher with proprioceptive stimulation alone. Overall, the amplitudes and speed of movement perceived did not differ between the stimulation conditions.

Conclusion: A therapy involving congruent proprioceptive and visual stimulation could be a relevant solution for patients with limited motor activity in the upper limbs to optimize sensory and perceptual rehabilitation. This may subsequently optimize the arm's functional activities.

Keywords: Vibration, virtual reality, proprioception, adults, sensory information.

P2-7

COGNITIVE LOAD AND GAME PREFERENCES IN THE GAMIFICATION OF NEUROREHABILITATION-CENTRIC HAND EXERCISES IN CHRONIC STROKE

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Background: Motivation and engagement are important factors to consider in the context of stroke rehabilitation. Enhancing both factors can lead to improved program adherence and therefore better rehabilitational outcomes for stroke participants. When exploring techniques to increase rehabilitation program appeal, gamification continues to be a popular means to enhance often mundane rehabilitative activities with proven results. Gamification applies game mechanics to non-game contexts to better engage audiences.

Methodology: Five gamified rehabilitative interfaces were developed and tested against a default non-gamified interface associated with hand function rehabilitation device (MyHand®). Participants with chronic stroke (Mean age: 54.4 ± 12.6 years, years since stroke: 2.3 ± 1.6 years) engaged in hand function training for 10-weeks. All participants completed a NASA-TLX questionnaire after each training session to help estimate cognitive load associated with the counterbalanced interface they interacted with. Total elapsed play time of each interface was also collected. Participants completed up to 24 sessions in total, with a maximum of 90 minutes of hand function training. For the first 30 minutes, participants trained using the non-gamified interface. For the following 60 minutes, one of 5 gamified interfaces or the non-gamified interface was interacted with. Breaks were included throughout the session. Pre- and post-assessment sessions were conducted with each participant before and after the intervention, capturing behavioural data. During the post-assessment session, participant game preference rankings of all six interfaces were also collected.

Results: The default non-gamified interface was consistently ranked as the least preferred interface among all participants (Interfaces were calculated to possess a preference weighting value between 7 to 42, the non-gamified interface had the lowest value of 7 whereas all gamified interfaces were between 21 and 37). In addition, the gamified interfaces, consisting of added complexity to incorporate game rules, themes, and strategy, did not add any additional cognitive burden onto participants compared to the default, non-gamified interface (no significant difference in cognitive load between gamified and non-gamified interfaces – $p>0.05$). Averaged weighted NASA-TLX scores confirmed the default non-gamified interface presented higher cognitive load score associated with gameplay compared to every gamified interface.

Conclusion: Overall, the preference for gamified rehabilitative interfaces and their decreased cognitive load was observed to be more effective in increasing potential adherence to stroke-based hand rehabilitation training.

P2-8

THE AUTONOMIC NERVOUS SYSTEM RESPONSE TO VISUAL-PHYSICAL INCONGRUENT WALKING CONDITIONS MEASURED BY HEART RATE VARIABILITY

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Background: The force of gravity critically impacts locomotion regulation. The central nervous system (CNS) is fed by multiple sensorial cues including vestibular, proprioceptive, and visual, which are being integrated to construct an updated assessment of the environmental state to change gait pattern accordingly. This self-regulation was explained by the *indirect prediction* (IP) model which suggests that first, neural constructs trigger pre-programmed gait patterns following destabilizing environmental changes detected by fast perceived cues (i.e., visual). Then after an iterative recalibration process of the relative influence of all sensorial cues leads to a gradual re-stabilization of gait, known as *sensory reweighting* (SR). In recent work, we formed a virtual reality (VR) environment in which the inclination of the visual scene is either congruent or incongruent (i.e., visuomotor incongruency) with the physical inclination of the walking surface. We found that purely visual cues induce consistent locomotor adaptations to counter expected gravity-based change.

The bilateral self-regulatory communication between the CNS and the executing effector is mediated also with the involvement of the autonomic nervous system (ANS), which is reflected, e.g., by cardiac function. Specifically, heart rate variability (HRV) represents the contribution of the parasympathetic nervous system (PSN) to cardiac regulation. Here we aim to investigate the sensitivity of cardiac function as expressed by HR (heart rate) and HRV measures to incongruent sensorial inputs (both in the IP and SR periods) and the associated locomotor response. Methodology: Fourteen healthy participants completed level-walking (L) trials in a fully immersive VR-system containing a self-paced treadmill (T) synchronized with visual (V) scenes while their HR was recorded. One trail conducted in vision-treadmill congruent conditions (TLVL), and others started visually leveled and transitioned to vision-treadmill mismatch (up-TLVU; down-TLVD). Based on congruent data, we calculated the HR to gait speed baseline relation (linear calibration) of each participant (Fig 1A). The percent difference between expected and measured HR and the root mean square of successive differences (RMSSD) were calculated.

Results: HR values extracted from visuomotor incongruency periods were significantly higher than values predicted by the calibration, reflected by positive error percentages (Fig 1B; left panel). RMSSD calculated from incongruent periods was significantly lower than in congruent periods (Fig 1B; right panel).

Conclusion: Virtual reality (VR) paradigms in the context of behavioral neuroscience enables the delineation of integrative perception-action behaviors across functional domains. Here we demonstrated that in addition to the modulated behavior in gait-speed, visuomotor incongruency had influence on the PNS response, as reflected by a decreased HRV, creating a residual increase of HR.

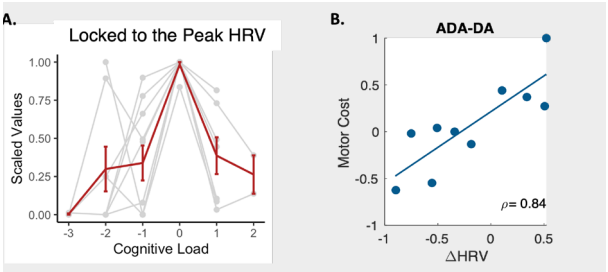

Fig. 1: Cognitive load and performance metrics; **A.** HRV patterns are aligned to each participant's peak HRV, with the peak labeled as 0, revealing an overall inverted-U-shaped response to cognitive load. Note: To standardize the response curves, the original four cognitive levels were spaced on a six-level scale on the x-axis. **B.** The correlation between HRV shift and changes in head-hand lag within the most challenging Trails (Arithmetic Divided Attention task; ADA - Divided Attention task ; DA).

Key words: sensory motor integration, gravity, incongruency, gait

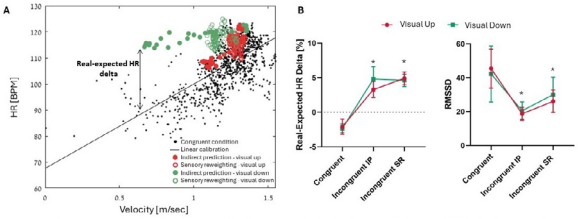

Figure 1: *Changes in HR and RMSSD values during incongruent periods of the trials.* **(A)** We calculated the HR to gait-speed linear calibration for each participant by means of data from congruent walking conditions (black dots; data of one participant). Differences between measured HR from the incongruent periods (colored dots in A) and the expected HR (fitted line in A) and the RMSSD measure for each period were calculated **(B)**.

P2-9

FEASIBILITY OF USING IMMERSIVE VIRTUAL REALITY IN PATIENTS AT AN INTENSIVE CARE UNIT

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Background: Patients in Intensive Care Units (ICU) often experience anxiety, fear, and depression. Stress factors include sensory overload and deprivation, isolation, temporal disorientation, and a feeling of lack of control. These symptoms are often a result of feeling vulnerable, lacking stimulation, and an inability to relax and sleep. Stress, anxiety, depression, and pain increase the risk of developing delirium. Immersive virtual reality (VR) was previously shown to be a promising means of diverting attention away from feelings of anxiety and thoughts of pain. The goal of this project was to assess the feasibility of VR use in ICU patients for distraction therapy that potentially can alleviate anxiety and pain and improve how they feel while in ICU.

Methodology: Twenty consecutive adult patients in the Medical Intensive Care Unit were consented to participate in the study. The patients were asked to use the VR headset for at least 5 minutes. They were offered a choice of immersive reality in a city, nature, or synthetic landscape. The visual analog scales were completed before and after the VR experience. On a scale from 1 to 10, the participants were asked (1) to indicate how they felt at the moment with 10 meaning fantastic, (2) to describe how worried/anxious they felt at the moment with 10 meaning extremely worried/anxious; and (3) to report how much pain they felt at the moment with 10 meaning they had the worse pain ever.

Results: The mean age of the participants was 61±17 years old ranging between 18 and 84 years old, and 45% of the patients were 65 years old or older; 75% of patients were males; and 94% of them didn't have previous experience with VR. Out of 20 enrolled patients, 19 completed the study. One patient withdrew before using VR because of a deteriorating condition. The nature, synthetic, and city landscapes were chosen by 26%, 21%, and 53%, respectively. The mean time spent in immersive reality was 9.7±2.7 minutes ranging between 5 and 14 minutes with a median VR session length of 11 minutes. After the VR session, the mean "feeling well" score increased from 6.5±2.1 to 8.4±1.7 ($p<0.0045$), the mean anxiety score decreased from 3.9±2.8 to 2.3±1.8 ($p<0.001$), and the mean pain score decreased from 3.9±2.8 to 2.3±2.0 ($p<0.0025$). All changes were statistically significant based on the paired t-test.

Conclusion: Even though the majority of patients were unfamiliar with VR, they were open to using VR as a potential means to improve their experience of ICU stay. A relatively short session of immersive reality resulted in a significant decrease in pain and anxiety, and an improvement in overall feeling well. We concluded that VR may be a potentially useful means of improving ICU patient care and that further investigation of this modality is warranted in larger and more representative patient samples.

Keywords: Virtual Reality, Intensive Care Unit, Distraction therapy

P2-10

CUEING-ASSISTED PERSONALISED AUGMENTED-REALITY EXERGAMING FOR PARKINSON'S REHABILITATION: STUDY PROTOCOL OF A RANDOMIZED CROSSOVER TRIAL

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Background: Reality DTx® is a new product with two core modules -*movement assistance and movement training*- that applies the existing proven principles of sensory cueing and home-based exergaming for people with Parkinson's disease (PD) onto augmented-reality (AR) headsets. These modules can be combined to provide cueing-assisted exergaming (Figure 1) to allow people with more severe mobility impairments to exercise at home. The exergames can be remotely prescribed and personalized by a physiotherapist. The objective of the this study in people with PD is to examine the clinical feasibility of home-based cueing-assisted personalized AR gait-and-balance exergaming with Reality DTx® in terms of safety, patient experience, and efficacy.

Methodology: 100 people with PD (Hoehn & Yahr 1-3) who experience bothersome gait and/or balance problems will participate in this randomized two-arm crossover study. The study consists of three in-clinic assessments. After a baseline assessment, half of the participants will start with an 8-week control period (i.e., usual care) while the other half starts with the 8-week Reality DTx® intervention. After 8 weeks, both groups will undergo a midterm assessments after which the groups switch roles, followed by a final assessment. Participants are invited to use Reality DTx®, with cueing when needed, five times a week for 30 minutes. A physiotherapist will remotely adjust the difficulty level of the exergames on a weekly basis. Main study parameters to evaluate the feasibility of home-based cueing-assisted personalized AR gait-and-balance exergames with Reality DTx® are safety (e.g., adverse events) and patient experience (e.g., perceived effectiveness and usability). In addition, standardized clinical gait-and-balance tests will be administered during the in-clinic assessments to evaluate the potential efficacy of Reality DTx®.

Results: Recruitment is expected to start in April 2024.

Conclusion: This study is the first study in which Reality DTx® will be used in a clinical setting. The results of this study will form the basis for future randomised controlled trials and provides guidelines for implemention of Reality DTx® in the clinic for people with PD.

Keywords: cueing, exergaming, augmented-reality headset, clinical feasibility, Parkinson's disease

Figure 1. Cueing-assisted boxing exergame to improve walking and balance.

P2-11

DEVELOPING AN ARTIFACT TO CONTROL MOTOR EXECUTION VARIABILITY IN VR-BASED PHYSICAL REHABILITATION

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Background: Virtual reality (VR) is known to increase engagement during motor function rehabilitation therapy. Increased engagement is associated with increased physical effort, which is critical to recovery. However, VR equipment has limitations when it comes to the assessment of motor learning or motor function recovery. For instance, the VR standalone controllers do not permit control of motor execution variability in VR-based motor function rehabilitation, which may hinder interpretability of research outcomes.

Methodology: In this ongoing study, we designed and evaluated an artifact for a VR-based pool billiard task. The artifact consisted of a rail and a pool billiard queue, on which the VR controllers were attached, permitting more realistic and guided motor execution. We evaluated and compared our artifact to the standalone VR controllers with 28 healthy subjects performing seven blocks of 30 consecutive and identical trials of a pool billiard shot. Subjects had to pocket a ball by controlling the landing location of the queue ball, which forced them to learn the optimal shot strength. After each block, we measured subjects' perceived performance and workload. At the end of the experiment, we measured subjects' sense of presence and upper limb muscles fatigue.

Results: Our results suggest that, compared to the standalone VR controllers, our artifact controlled for variability in motor execution, strengthening interrelationships between subjects' sense of presence and perceived performance, workload, and muscle fatigue. However, our evaluation also suggests that the weight and friction of our artifact caused discomfort and muscle fatigue, which may confound therapeutic efficaciousness. We are currently evaluating an improved version of our artifact that is significantly lighter and that reduces the friction and torsion in the movement compared to our initial design. Pre-tests with the new iteration show promising preliminary results in reducing the variability of motor execution even further, without the confounding effects of discomfort and fatigue.

Conclusion: These preliminary results suggest the methodological benefit of using an artifact to control motor execution variability in VR-based motor function rehabilitation. In future work, we will test our improved artifact with stroke patients suffering from upper limb motor function impairments.

Keywords: Virtual Reality, Physical Rehabilitation, Artifact Design, Motor Execution

P2-12

CO-DESIGN AND DEVELOPMENT OF IMMERSIVE VIRTUAL REALITY SERIOUS GAMES FOR UPPER LIMB REHABILITATION

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Background: Stroke is a leading cause of death and adult acquired disability worldwide, with about 40-50% of Stroke survivors experiencing impairments in the upper limb (UL). Research into the use of Serious Games (SG) and Virtual Reality (VR) interventions to augment rehabilitation therapy is growing due to the increasing need for interventions, but this demand is unfortunately not matched with sufficient rehabilitation personnel needed to provide personalised rehabilitation interventions. Promising results have been observed so far with the use of 3D immersive SG in VR for UL and cognitive rehabilitation, although challenges associated with rehabilitation experiences e.g. fatigue, monotony, demotivation, and lack of engagement persist. Unfortunately, commercial games that have been used for UL rehabilitation do not always factor the unique needs of people with disabilities and how their gaming experiences and feedback are delivered to optimise rehabilitation outcomes.
The aim of this study was to co-design immersive VR SGs for UL rehabilitation for people with stroke by incorporating both end-users and rehabilitation clinical teams' insights.

Methodology: Based on a virtual kitchen setting, sketches were made of potential games that involve several UL movements based on neurorehabilitation and gamification principles, and assessments from standardised outcome tests. Semi-structured interviews (hybrid) were conducted with physio – and occupational physiotherapists (n=5) and their feedback were used to refine the games' storyboard and prototypes developed in the Unity Game Engine, which was demonstrated to a focus group of people with Stroke and spinal cord injury (n=3).
The interviews and focus groups were transcribed, coded and themes developed via thematic analysis using NVivo 14.

Results: Some important themes identified from patients' perspective include communication type, rehabilitation site and affect. Codes revealed they were *"not too bothered about aesthetics"* as far as rehabilitation potential was evident. Most did not have much gaming experiences but were open to trying. Some game elements identified as vital were positive and real-time feedback, improvement metrics, optional audios and preventing boredom.
Clinicians observed that games would be good for motor priming; are feasible for task-specific training and can be motivating for patients with little or no movement via an exaggerated movement in VR.
Both clinicians and end-users agreed with the potential for cognitive rehabilitation.

Conclusions: A co-design approach is recommended for developing VR SGs for rehabilitation as it factors patients' unique needs, helps them appreciate exercises being done with not on them and are not being "punished" for inability to perform a movement. Simple prompts in the games can help mitigate the telerehabilitation barrier of "*technical jargon*".

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P2-13

OBSTACLE CIRCUMVENTION DURING OMNIDIRECTIONAL TREADMILL WALKING IN VIRTUAL REALITY

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Background: The ability to circumvent obstacles is an important skill for safe community ambulation. Such ability entails adapting the speed and direction of walking to circumvent the obstacle while progressing to the end goal. While obstacle circumvention is an integral component of locomotor rehabilitation, opportunities to practice such skill in environments that mimic community walking remain limited within clinical settings. The combined use of virtual reality (VR) and omnidirectional treadmills (ODTs), which allow for speed and directional changes, provides the means to train such skills in ecological, yet safe and controlled conditions. The extent to which obstacle circumvention strategies on an ODTVR set-up differ from those observed when walking overground in the physical world (OVGPW), however, remains to be determined and was the object of this study.

Methodology: Fifteen healthy young adults (18-29 yrs) were assessed while randomly exposed to the OVGPW and the ODTVR condition. In the OVGPW condition, they walked in the laboratory towards a target while avoiding a static male interferer located 3m or 3.5m ahead. In the OVGPW condition, they performed the same task while walking on the ODT (Infinadeck) and visualizing the virtual laboratory and interferer in a head-mounted display (HTC Vive ProEye). A familiarization with the ODTVR condition was provided prior to testing. Four blocks of 6 trials were performed for each condition. Vive trackers and a Vicon system were used to capture participants' position in virtual and physical coordinates. Minimum distance maintained from the interferer, distance at onset of trajectory deviation and average walking speed were compared across conditions and blocks using generalized estimating equations.

Results: Participants maintained larger minimum distances ($p<0.01$: =0.19m) and slower walking speeds ($p<0.001$: =0.41m/s) in the ODTVR vs. OVGPW condition, while a non-significant ($p=0.05$) trend towards smaller onset distances of deviation was observed for the ODTVR condition (=0.13m). A significant effect of bloc was observed exclusively for walking speed ($p=0.01$). This speed difference occurred exclusively between the first and second bloc of trials (=0.07 m/s) for both conditions.

Conclusion: The larger minimum distances and slower walking speeds in the ODTVR condition suggest that this condition yields more conservative obstacle avoidance strategies compared to when walking in a 'real-life' condition. This could be explained, in part, by the treadmill control mechanism, unfamiliarity with the ODTVR set-up and alterations in depth perception induced by VR. Present findings further suggest that despite practice, differences between conditions persist, at least within a single session. Before this ODVT-VR set-up can be used in the context of rehabilitation, further research is needed to extend the present findings to multiple sessions and patient populations.

Keywords: Locomotion, pedestrian, obstacle avoidance, omnidirectional treadmill, virtual reality

Acknowledgement: This study is funded by CIHR.

P2-14

EFFECTIVENESS OF BALANCE TRAINING POST-STROKE THROUGH EXERCISES THAT COMBINE MOTOR AND COGNITIVE DEMANDS IN INDIVIDUALIZED VIRTUAL REALITY-BASED ENVIRONMENTS

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Background: Balance, mobility, and upper limb impairments are common motor deficits after stroke. Virtual reality (VR) can potentially overcome some limitations of conventional rehabilitation approaches through personalized exercises, augmented feedback, and goal-oriented tasks. However, performance of daily activities requires complex execution combining motor and cognitive skills in real-world environments, which can be different from those simulated in common virtual environments.
We have developed a non-immersive VR system that integrates actual photographs of living spaces and allows for the placement of various interactive items within different game scenarios. These games entail identifying and/or positioning items correctly by reaching for them with the upper limbs, executing lateral steps, and making postural adjustments, all while utilizing attention, memory, and executive functions. The aim of this study was to determine the effectiveness of the VR system in a sample of individuals post-stroke.

Methodology: Individuals post-stroke aged 18 to 70 years, more than 6 months post-injury, without severe cognitive deficits, and with safe standing were enrolled. Ten subjects (40% women), with a mean age of 58.4±10.7 years and a time post-injury of 11.8±8.4 months, participated in the study.
Participants were asked to provide photos of their kitchens, where the location of a list of over 150 food items, cutlery, utensils, and kitchen instruments was identified with the assistance of a therapist and a relative (if needed).
The intervention consisted of 20 sessions of 20 minutes of conventional physiotherapy plus 20 minutes of interaction with the VR system, divided into 6 minutes for each of the 3 exercises (grocery sorting, search and find, and sequence recall) with 1 minute of rest between them. Participants' balance and gait were assessed before, after, and one month after the intervention using the Berg Balance Scale, Functional Reach Test, Four Square Step Test, and 10 Meter Walk Test.

Results: The patients' condition significantly improved post-intervention, as evidenced by results across all scales and tests (Table 1). Importantly, the improvement was sustained one month after the intervention, with the ability to step forward, sideways, and backward continuing to improve according to the Four Square Step Test.

Conclusion: The combined training of motor and cognitive abilities through conventional and gamified VR-based training enables improving balance skills in individuals with chronic stroke. Future studies will seek to compare the effectiveness of this intervention with conventional therapy and examine how well the benefits gained in the simulated virtual environment transfer to real-life settings.

Keywords: balance, stroke, virtual reality, physical therapy, occupational therapy.

Acknowledgement: This study was supported by Conselleria d'Innovació, Universitats, Ciència i Societat Digital of Generalitat Valenciana (CIDEXG/2022/15) and by Ministerio de Ciencia e Innovación (PID2022-141498OA-I00).

P2-15

NEUROPHYSIOLOGICAL RESPONSES TO IMMERSIVE VIDEOS OF RELATIVES AND STRANGERS. PRELIMINARY FINDINGS ON HEALTHY SUBJECTS AND PATIENTS WITH DISORDERS OF CONSCIOUSNESS

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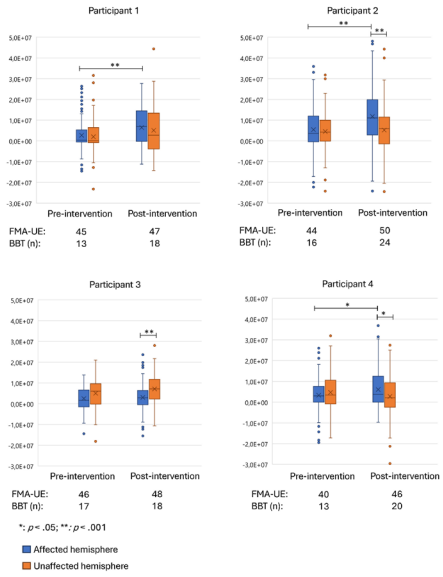
Background: Severe acquired brain injuries can lead to disorders of consciousness (DOC), including the unresponsive wakefulness syndrome (UWS), and the minimally conscious state (MCS), where patients have very limited responses to external stimuli. Bedside assessment of the neurobehavioral condition though clinical instruments has been reported to have a significant misdiagnosis rate. Multimodal assessments using neuroimaging and neurophysiological examinations, such as electroencephalography (EEG), have been recommended to improve the accuracy of the diagnosis.
An important body of research in healthy subjects has shown that certain EEG features in different frequency bands are associated to emotion recognition during audiovisual stimulation. Studies in patients with DOC, in contrast, are limited but suggest that personalized stimuli, like the self-own name or familiar voices, can influence the responses of patients with DOC.
This study aims to investigate differences in the EEG responses of a sample of healthy subjects, patients in MCS, and patients with UWS in response to emotional videos of their relatives or strangers.

Methodology: A convenience sample of 17 healthy subjects, 5 patients in MCS and 6 patients with UWS participated in the study.
The experiment involved a one-minute baseline period followed by 12 55-second videos (six featuring relatives and six featuring strangers) displayed in random order, each followed by a resting period. Videos were displayed using the HTC Vive Pro Eye 2 virtual reality headset. EEG was recorded using a 32-channel amplifier, the Brain Products LiveAmp. EEG recordings were conventionally preprocessed. Signals were windowed into 2-second segments, and power spectral density (PSD) and differential entropy (DE) were extracted for alpha, beta, gamma frequency bands in frontal channels. These features were normalized to the mean precedent resting window. Mann-Whitney U tests, with Bonferroni corrections, were conducted to compare the differences in features between videos of relatives and strangers for each group of participants.

Results: Healthy subjects, patients in MCS and patients with UWS showed different brain responses to videos featuring relatives and strangers (Figure 1). Videos featuring relatives elicited different responses between these groups for almost all investigated features and electrodes.

Figure 1. Changes in the oxygen levels in the affected and unaffected hemisphere and in the motor function



Conclusion: These preliminary findings suggest that the processing of emotional videos is affected by the clinical condition. Future studies will use machine learning models to investigate differences in the brain responses of patients with DOC to videos of relatives and strangers that can evidence certain degree of covert cognition and, consequently, improve diagnosis.

Keywords: virtual reality, emotion recognition, neurophysiology, disorders of consciousness, diagnosis.

Acknowledgement: This study was supported by Conselleria d'Innovació, Universitats, Ciència i Societat Digital of Generalitat Valenciana (CIDEXG/2022/15) and by Ministerio de Ciencia e Innovación (PID2022-141498OA-I00).

P2-16

KNOWLEDGE, PRACTICE, AND ACCEPTANCE OF PHYSIOTHERAPISTS ABOUT THE USE OF IMMERSIVE VIRTUAL REALITY IN CLINICAL PRACTICE: AN INTERNATIONAL ONLINE SURVEY

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Background: For several years now, the use of immersive virtual reality (VR) has been studied as an intervention in physiotherapy. This new means of rehabilitation, which can be used not only in hospitals but also at home and in private practice, is promising and appears to be as effective as established treatments. Although the number of studies demonstrating the effectiveness of immersive VR in physiotherapy is growing, its implementation in clinical practice remains relatively low. At present, we do not know the reasons for the lack of use of immersive VR in clinical practice among physiotherapists. Various hypotheses could be envisaged, such as a lack of knowledge or negative attitudes towards it. Conversely, we don't know the exact reasons why some physiotherapists decided to use immersive VR in their clinical routine. The aim of the cross-sectional survey is to investigate the knowledge, practice, and acceptance of physiotherapists about the use of immersive VR in clinical practice.

Methodology: Physiotherapists from different French-speaking and Dutch-speaking countries (such as Belgium, Canada, France, Switzerland, the Netherlands, Luxemburg) will be recruited using non-probability sampling. The survey will be available online on LimeSurvey software for a period of 4 months. The questionnaire will include questions about general information (age, gender, number of years in practice, etc.) and several sections assessing knowledge, practice, and acceptance of use (based on the Unified Theory of Acceptance and Use of Technology) of immersive VR in clinical practice.

Results: The questionnaire was pre-tested on 20 physiotherapists from Belgium, France, Luxemburg, Canada, and the Netherlands. The survey will begin the week of February 19, 2024, and end the week of June 19, 2024. We hope to recruit at least 300 physiotherapists and are confident of reaching this number long before the congress. The survey will be completed before the congress.

Conclusion: No conclusions can be drawn to date, as no data have been collected. This study is the first to investigate the knowledge, practice, and acceptance of physiotherapists from different countries around the world about the use of immersive VR in clinical practice. This investigation could lead to a better understanding of the current (non)implementation of this means of rehabilitation in physiotherapy, and help develop ways to better implement it in physiotherapists' clinical practice.

Keywords: Immersive virtual reality, physiotherapists, survey, clinical practice, cross-sectional

P2-18

A STUDY PROTOCOL INTO FEASIBILITY AND ACCEPTANCE OF A VIRTUAL REALITY SYSTEM THAT PROVIDES IMMERSIVE EXPERIENCES DURING ROBOT ASSISTED WALKING TRAINING (LOKOMAT) FOR PEOPLE WITH NEUROLOGICAL CONDITIONS

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Introduction: Functional gait recovery is very important for neurological patients and is a main goal of their rehabilitation program. Recently, new technologies for gait training have emerged. For example, robot-assisted gait training (RAGT) is a safe way of treadmill training that reduces therapists' physical demands and allows early and frequent gait training in the rehabilitation process. In RAGT, different training parameters, such as: treadmill speed, body weight support, or leg motion support, can be changed to create an optimal training intensity. Feedback and gamification are used to increase engagement and motivation of patients during such training. Immersive Virtual Reality (IVR) is a new approach to further engage and motivate patients during RAGT and has the potential to apply relevant neuroplasticity concepts, i.e. task oriented, repetitive, and intensive training. Virtual Reality (VR), both through screen-based games and Head Mounted Displays (HMD), has become more popular in rehabilitation, but there is not enough evidence for its feasibility and effectiveness for use in RAGT.

Objectives: To investigate the feasibility of using an IVR system during RAGT in subjects suffering from neurological disorders, and to assess the acceptance of the setting in a clinical environment.

Material and methods: This feasibility study was performed at the University Rehabilitation Institute, Republic of Slovenia, Department for rehabilitation. This study included participants after stroke or with incomplete spinal cord injury. The participants used a LokomatPro® system version 6 while wearing an HMD: Oculus Quest II during one session (Figure 1). The IVR application connects to the Lokomat over a wireless local network and maps the Lokomat orthosis angles to the patient's avatar, so that looking down with the HMD will show the avatar's legs moving synchronized to the patient's actual leg movements. Each session on Lokomat will last from 30 to 45 minutes with the intermediate rests. Walking speed will be progressively increased to a comfortable level.

Results: Ten stroke and five SCI patients participated in the study. Fourteen were in subacute and one in chronic phase. The mean in the Functional Ambulatory Scale of the participants was 3.4. The duration of the session lasted an average of 20 minutes (sessions from 10 to 32 minutes). None of the patients reported adverse events or side effects. All the participants and therapists underwent questionnaires about the acceptance of IVR, and the results were positive from each of them.

Conclusions: Participants and therapists showed high acceptance of IVR in combination with Lokomat. However, the therapists needed further improvement of usability, as well more options for adaptation to individual needs.

Fig 1 . A. LokomatPro® system version 6; B. Oculus Quest II.

P2-19

VIRTUAL SEDATION AS A SUBSTITUTE FOR PHARMACOLOGICAL SEDATION: FROM VASCULAR ACCESS TO SURGICAL PROCEDURES

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Background: Adult and pediatric patients are often subjected to painful medical procedures resulting in emotional stress and behaviours that impact both their quality of life and the procedure's execution. To deal with these problems, sedation is normally used. However, in both pediatric and adult patients it involves risks of even serious side effects and significant organizational costs for the hospital. The need to improve patient's quality of life while limiting drug administration, also recognized by the latest "Infusion Therapy Standards of Practice" [1], has led to the exploration of the benefits of using a drug-free digital solution based on virtual reality (VR).

Methodology: Following a series of successful studies completed between 2022 [2] and 2023, our interdisciplinary research team has focused on the integration of the MAYA VR project across several Italian healthcare facilities to meet the diverse needs of patients - ranging from pediatric to elderly - during vascular access procedures. Furthermore, we have innovatively combined VR with local regional anaesthesia during surgical operations, a breakthrough that eliminates the need for sedation solely for patient comfort, thereby mitigating the risk of adverse reactions, which are particularly significant among vulnerable populations (including the elderly and those with co-morbidities) such as nausea, vomiting, dizziness, and disorientation, and the overall patient experience during and post-procedure.

Results: Preliminary results suggest a significant reduction in pain and anxiety and a substantial improvement in patient comfort, short preparation time and an estimated significant reduction of costs associated with the involved procedures, due to the replacement of traditional sedation with the digital, VR-based alternative.

Conclusion: Immersive technologies emerge as a safe, valid and cost-effective alternative to traditional sedation in patients undergoing invasive medical procedures and/or with a predominant dose of anxiety and fear, improving the patient's experience within the hospital. A pain-free hospital that supports patients during the most difficult moments such as surgery is possible with virtual sedation.

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P2-20

A NOVEL XR USE CASE FOR VISUALIZING MOVEMENT AND PERFORMANCE IN UPPER LIMB REHABILITATION: INNOVATIONS FROM THE XREHAB PROJECT

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Background: Motor rehabilitation is crucial for patients recovering from conditions that impair movement, such as strokes or injuries. Traditional rehabilitation methods often lack engagement and real-time feedback, which are essential for motivating patients and tracking progress. The integration of Extended Reality (XR) into rehabilitation practices offers a promising solution by providing immersive, interactive environments that encourage patient participation and enable precise monitoring of therapeutic outcomes.
This use case explores the application of XR technology in upper limb rehabilitation, focusing on an innovative approach that visually integrates the patient's interaction with a physical table into the virtual environment. The aim is to enhance the rehabilitation process by offering real-time visualization of the range of motion (ROM) in the upper limb across three planes, thereby providing both the patient and therapist with immediate feedback on performance and progress.

Methods: This use case employs XR technology to create a seamless integration between the physical and virtual worlds. The Meta Quest 3 was used as hardware because of the inside out body tracking and accurate hand tracking. When a subject places their hands on a table, the table is instantaneously visualized within the VR environment. This visualization aids in grounding the patient's experience in reality while interacting with the virtual space. Subsequently, the system calculates and displays the subject's ROM in the sagittal, frontal, and transverse planes, making this information accessible to both the patient and the therapist in real-time. Based on these visualizations, a series of sample exercises are generated, tailored to challenge the subject's current capabilities and encourage improvement. These exercises are designed to be repeatable, allowing subjects to strive to surpass their previous best performances, thereby fostering a sense of progression and achievement.

Results: User experience research from therapists and patients will be collected from February to May 2024. Preliminary feedback from the implementation of this use case indicates a positive impact on patient engagement and motivation. The immediate visualization of the physical table within the virtual space enhances the user's immersion and comfort. Moreover, the real-time display of ROM and the ability to track improvements over time empower patients and therapists with valuable insights into the rehabilitation journey.

Conclusion: XR can be an interesting tool to train motor skills and has a clear added value to standard therapy. Hand tracking and visual feedback are very unique possibilities in XR allowing exercises to be adapted to the subject's unique profile. The integration of XR technology into motor rehabilitation represents a significant advancement in the field, offering novel methods for enhancing patient engagement and motivation.

P2-21

IMMERSIVE VIRTUAL REALITY FOR PSYCHOSOCIAL MANAGEMENT AND FUNCTIONAL RECOVERY IN A PATIENT WITH TIBIAL PLATEAU FRACTURE: A CASE REPORT

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[1]*Universidad San Sebastián,* [2]*Clínica MEDS - Calera de Tango*

Introduction: Musculoskeletal disorders can generate significant physical and emotional distress, hindering functional recovery. This case report presents the use of immersive virtual reality (IVR) with a psychosomatic approach to address pain, anxiety, and kinesiophobia in a 35 year old female patient with a tibial plateau fracture with surgical resolution.

Case description: The patient suffered a traumatic right knee injury during a Padel match, resulting in severe pain and inability to move her knee, being diagnosed with a tibial plateau fracture with tibial detachment. She underwent surgery and was prescribed 10 physiotherapy sessions. After 5 sessions, during 2 weeks, she presented with limited range of motion, 20° knee flexion, decreased muscle trophism (M1-M2 Daniels), decreased muscle activation in quadriceps, severe anxiety, kinesiophobia, sensibilization and catastrophizing. She was also emotionally labile, with feelings of tachycardia during movilizations and sleep disturbances.

Intervention: A single VR intervention was conducted. The patient's emotional triggers were identified (related with her family and work environment), and a VR experience was tailored to address them. It included: (1) Sensory and emotional identification of pain in extreme virtual environments (The Climb 2, 5 minutes); (2) guided meditation with box breathing and an aquatic world (TRIPP, 20 min), to promote relaxation, while a therapist performed passive mobilization of the right knee; and (3) boxing training with load tolerance on both knees (FIT XR ,10 min) in a seated position for distraction.

Outcomes: The patient reported feeling better, with reduced anxiety and pain (EVA 1-2/10). Range of motion increased to 90° knee flexion, and muscle activation improved. Two days later, a functional evaluation showed 110° knee flexión and further improvement in anxiety and pain, avoiding re-entering surgery to release the knee.

Conclusion: This case demonstrates the potential of IVR with psychosomatic approach to enhance functional recovery and address the emotional aspects of musculoskeletal disorders. IVR technology allows the patient to identify and understand their injury from a socio-affective and psycho-emotional perspective, and can provide a cost-effective and engaging way to improve patient outcomes and reduce healthcare costs.

Keywords: Tibial plateau fracture, rehabilitation, immersive virtual reality, psychosomatic approach, physiotherapy, anxiety, pain, functional recovery

P2-22

QUESTIONNAIRES FOR EVALUATING VIRTUAL REALITY: A SCOPING REVIEW

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Introduction: Virtual reality (VR) is an emerging technology in fields like education, healthcare, and entertainment. A challenge for VR researchers is knowing what VR evaluation instruments exist, and which best align with their objectives. Therefore, a systematic scoping review was conducted to identify and appraise existing questionnaires that evaluate VR.

Methods: A scoping review across five scientific databases identified Dutch or English, peer-reviewed articles that described the development of new and/or modified questionnaires that evaluated VR. All identified articles were independently screened by two researchers and data about the measured constructs, (psychometric) properties, and availability of these questionnaires was extracted.

Results: The initial search identified 3697 articles, 125 were full text screened, and 50 were included in the review. In total, seven constructs were measured to evaluate VR, of which presence (n = 26, 52%), user experience (n = 10, 20%) and cybersickness (n = 5, 10%) were most commonly measured. However, these constructs were not always clearly defined, and measures of the same construct often differed in their content. Reliability ranged from unacceptable to exceptional and was reported in 29 questionnaires (58%), evaluations of validity were found in 37 (74%) questionnaires and included face, content, construct, and criterion validity. An overview of questionnaire availability, translations, and modifications was provided. Moreover, recommendations per construct on the most optimal VR questionnaires were proposed (based on e.g. content, usability and psychometric properties).

Discussion: A wide range of questionnaires used to evaluate VR were identified. Further, explorations of VR-related constructs (e.g. presence, user experience and cybersickness) were done by comparing definitions, exploring questionnaire items, and examining their differences. Where relevant, constructs were divided (e.g. presence was divided into social, self, and spatial presence) and suitable definitions for each (sub-)construct were given. It was recommended to use a structured approach when designing and developing a questionnaire (e.g. including psychometric properties) and to specify the choice of constructs and their definitions. Finally, directions for the development of future questionnaires (e.g. virtual therapist alliance) to evaluate VR were provided.

P2-23

GAIT AND BALANCE ASSESSMENTS WITH HOLOLENS 2 AND MAGIC LEAP 2 IN PEOPLE WITH PARKINSON'S DISEASE: CONCURRENT VALIDITY AND TEST-RETEST RELIABILITY

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[1]*Vrije Universiteit Amsterdam*

Background: Microsoft's HoloLens 2 (HL2; Figure 1; left) and Magic Leap (ML2) are augmented-reality (AR) headsets that capture headset position (Figure 1; middle and right) and orientation data, enabling measurements and analyses of clinical gait-and-balance tests. A good quantification of (sub) durations of these tests using AR data could establish it as a wearable measurement system in the home environment of people with Parkinson's disease (pwPD). This approach would eliminate the need for visits to external measurement locations, as assessments could be conducted at higher measurement frequencies in people's home environment. The objective of this study was to evaluate concurrent validity and test-retest reliability of AR data in quantifying (sub) durations during several clinical gait-and-balance tests for pwPD.

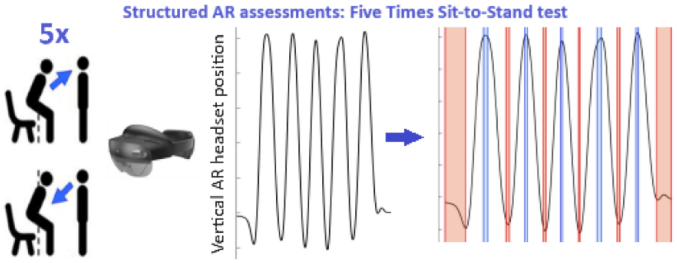

Figure 1. Left: The Five Times Sit to Stand (FTSTS) test with Microsoft's HoloLens 2 (HL2). Middle: Vertical AR position data of the FTSTS test. Right: In the vertical AR position data , sitting, standing and transfer movements (i.e., sit-to-stand and stand-to-sit) can be detected. Red bars represent sitting episodes, blue bars represent standing episodes and the white spaces in between represent either sit-to-stand or stand-to-sit transfer movements.

Methodology: 22 pwPD performed several clinical gait-and-balance tests: the Five Times Sit to Stand (FTSTS) and Timed Up and Go (TUG) tests. Position and orientation data of the headset was collected using the HL2 and the ML2 to calculate total durations and durations of specific segments, such as sit-to-stand, turning and walking. These outcome measures were concurrently measured by two gold standards: a stopwatch for total durations, and McRobert's Dynaport MoveTest (DMT) for both total durations and sub durations. Intraclass Correlation Coefficient (ICC) and Bland-Altman's bias and limits of agreement (LoA) were used to evaluate concurrent validity (agreement between systems) and test-retest reliability (consistency over repetitions).

Results: Results indicated excellent concurrent validity and test-retest reliability for total durations of FTSTS and TUG tests (ICC > 0.75). Sub durations demonstrated good overall validity and reliability (ICC > 0.60) for both tests. Between-systems agreement generally resulted in higher ICCs and narrower LoA, indicating better between-systems agreement than between-repetitions agreement.

Conclusion: In conclusion, this study revealed that (sub) durations of clinical gait-and-balance tests can be validly and reliably quantified using AR data in pwPD. Optimization of the algorithm is recommended for the detection of some specific segments. Nevertheless, HL2 and ML2 AR data are of sufficient quality to assess gait and balance in pwPD.

Keywords: Augmented Reality; Parkinson's Disease; Gait-and-Balance Tests; Concurrent Validity; Test-Retest Reliability.

P2-24

A SCOPING REVIEW OF FRAMEWORKS EVALUATING DIGITAL HEALTH APPLICATIONS: SCALE-UP4REHAB PROJECT

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Background: Rehabilitation is crucial for enhancing population health and health system efficiency. Virtual Reality (VR) offers an opportunity for efficient, location-independent rehabilitation, however current virtual rehabilitation therapies often lack scalability. The Scale-Up4Rehab project is establishing an open North-West Europe virtual rehabilitation 'clinic' to scale up existing virtual reality therapies. One of the initial activities of the Scale-Up4Rehab project will be to create an approval process for the rehabilitation applications that will be hosted on the virtual 'clinic'. To inform the criteria for this, a scoping review was undertaken to identify existing high-quality frameworks for evaluating digital health applications and analyze those frameworks for insights into designing criteria.

Methodology: This scoping review included a search strategy of relevant keywords which encompass terms for the domains of interest: 'evaluation frameworks' and 'digital health applications'. Articles obtained following the literature search were exported and saved into an online review management platform (Rayyan). Titles and abstracts of studies were independently screened for inclusion and exclusion criteria by two reviewers. Full texts of the remaining studies were reviewed independently by two reviewers for their eligibility. The data extracted from the papers included: authors and dates of publication, source affiliation, country of origin, name of framework, description of framework, intended users, and categories/questions of assessment used to evaluate the application. In addition, a search of the grey literature was conducted to identify any additional evaluation frameworks not captured in the scoping review search.

Results: A total of 5151 potentially relevant articles were found through a literature search across seven databases: ACM, IEEE, Pubmed, Cinahl, Scopus, Embase, and SportsDiscus. In the process of study selection, screening based on inclusion and exclusion criteria resulted in 165 articles. Following a review of the full texts, 19 articles fulfilled the inclusion criteria. National and international frameworks evaluating digital health applications were identified in the included articles. They included a broad spectrum of categories and sub-categories for example evaluation of regulatory approval, technical stability, clinical assurance/safety, and application effectiveness.

Conclusion: The large number of digital health application frameworks identified in the review highlighted the broad scope of categories that are considered necessary for the effective evaluation of digital health applications. The results from this scoping review will contribute to the criteria development for the approval process for online rehabilitation applications within the Scale-Up4Rehab project.

Keywords: Scoping Review, Frameworks Evaluating Digital Health Applications

P2-25

COGNITIVE FLEXIBILITY TRAINING IN VIRTUAL ENVIRONMENT FOR PATIENTS WITH OBSESSIVE COMPULSIVE DISORDER

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Backround: Obsessive-compulsive disorder (OCD) is characterized by obsessions (intrusive thoughts) and compulsions (ritualized behavior). Patients with OCD can also have impairments in cognitive flexibility (CF), which may result in a decreased ability to shift between mental processes and adapt their behavioral response to environmental changes (Gruner and Pittenger 2017). To target the FC impairments we created VR-based cognitive training methods. The aim of this study is to evaluate this method as a potentially valuable addition to cognitive behavioral therapy.

Methodology: The inpatients undergo either cognitive training (VRCT group) or exposure therapy in VR (VRET group, for details see Fajnerová & Francová, 2023) using immersive virtual reality (VR). The environment for training consists of three cognitive tasks with difficulty of the tasks increasing between/within sessions. Both groups have 4-5 sessions, once a week. Before the first and last VR session, we assess participants' cognitive flexibility by the Cognitive flexibility inventory and Barrat impulsiveness scale. CF subtypes are assessed using the Stroop test, verbal fluency test, Trail Making Test A and B (TMT) and PEBL software Go/Nogo task and Berg's Card Sorting Task (BCST). Symptom severity is assessed using Yale Brown Obsessive-Compulsive Scale. Before and after each training session current anxiety levels are measured with subjective scales.

Results: We will present preliminary results from the ongoing clinical study (n = 20). We will evaluate the scores from the neuropsychological assessments and questionnaires before and after the sessions in VR and in comparison with the control group (VRET). There is an observable CF improvement in some of the test methods (TMT A, VF, Go/Nogo task) in the VRCT group.

Conclusion: The cognitive flexibility training in VR was demonstrated as a feasible method, but a larger clinical sample is needed to evaluate its effectiveness.

Keywords: Obsessive-compulsive disorder, cognitive flexibility, virtual reality, cognitive training

Acknowledgments: The presented study is supported by the Czech Health Research Council (AZV R) project NU23-04-00402 "Exposure therapy in virtual reality for obsessive-compulsive disorder: randomized clinical study" and by the program Cooperatio Neurosciences, 3rd Faculty of Medicine, Charles University.

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P2-26

EFFECTS OF VIRTUAL REALITY TRAINING ON PAIN INTENSITY AND DISABILITY IN PATIENTS WITH CHRONIC LOW BACK OR NECK PAIN: A SYSTEMATIC REVIEW WITH META-ANALYSIS

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Background: Virtual reality (VR) is an emerging option for treating chronic spinal pain. For chronic conditions, VR technology offers a dual purpose: cognitive rehabilitation (teaching cognitive behavioral therapy or pain neuroscience principles), and physical rehabilitation (performing exercise in a virtual environment). Patients can benefit from VR technology because its distraction mechanism reduces cognitive capacity for processing pain signals. By involving patients in their recovery through an entertaining, engaging and interactive approach, VR also promotes motivation and adherence throughout the rehabilitation process. The aim of this study was to determine differences in the short-term effects of VR training on pain intensity and disability in patients with chronic low back pain (CLBP) and chronic neck pain (CNP).

Methodology: We searched PubMed, Scopus and PEDro databases for studies examining the effects of VR training on pain and disability compared with conventional therapy in adults with CLBP or CNP. Using a meta-analysis with a random effects model, we derived the standardized mean difference as a pooled effect.

Results: We found 14 studies that were eligible for meta-analysis. Eight studies examined patients with CNP (8 studies assessed the effects of VR on pain intensity and 6 on disability), while six studies examined patients with CLBP (5 studies focused on the effects of VR on pain intensity and 3 on disability). Most studies were of good methodological quality (6-8 points on the PEDro scale). When comparing effects of VR and non-VR exercise programs on disability, the SMD was greater in CNP patients than in CLBP patients (–0.49 and –0.05, respectively), suggesting potentially greater effectiveness of VR exercise programs on disability in CNP compared to CLBP. However, VR programs did not significantly improve disability in either CLBP (95%CI = –0.57 to 0.48; I2 = 58%; p = 0.860) or CNP patients (95%CI = – 1.05 to 0.06; I2 =78 %; p = 0.08) compared to non-VR programs, suggesting that there is no short-term benefit to incorporating VR interventions into exercise programs if disability is to be improved. For pain intensity, the effect favoured VR over non-VR interventions in CLBP patients (SMD = –0.61; 95%CI = –1.06 to –0.16; I2 = 57 %; p = 0.008), while for CNP patients the effect was not statistically significant (SMD = -0.50; 95% CI = -1.10 to 0.09; I2 =85 %; p = 0.10), suggesting that VR interventions do not significantly reduce pain intensity in this group.

Conclusion: Potentially greater success in improving disability with VR interventions compared to non-VR interventions was observed in CNP patients than in CLBP patients. Conversely, VR interventions may be more successful in reducing pain in CLBP patients than in CNP patients.

Keywords: chronic pain, spinal pain, virtual rehabilitation.

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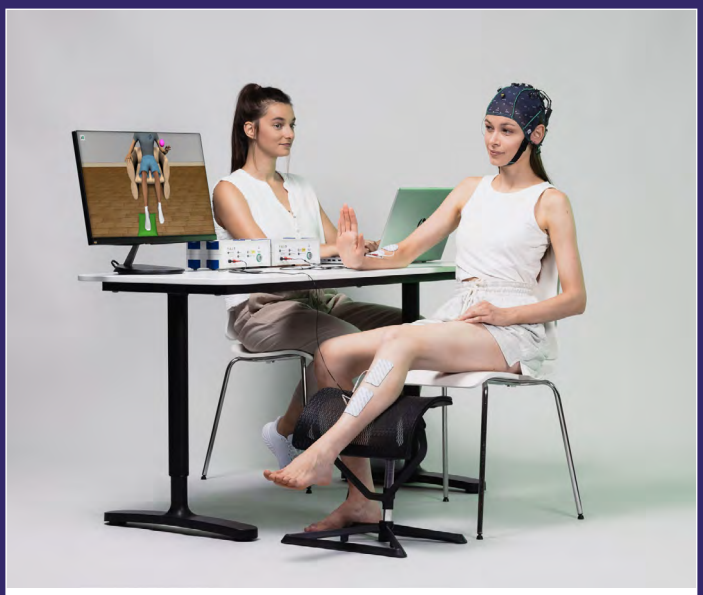

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