Virtual Reality Rehabilitation following Traumatic Brain Injury

Rehabilitation
Laura Fergusson Trust
Canterbury

Interdisciplinary, Collaborative Team

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  - Cerebral Fix

University of Otago
Te Whare Wānanga o Otāgo
New Zealand

CallaghanInnovation
New Zealand's Innovation Agency

CEREBRALFIX

Acknowledgements

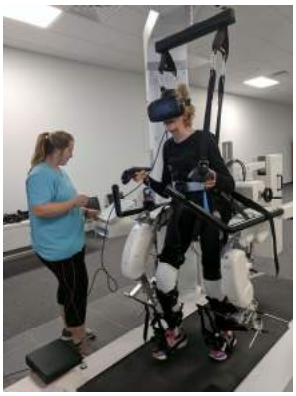
- Support from MedTech Centre of Research Excellence (CoRE)
  - Concept development funding
  - Future pilot trial

Virtual Reality

- What is Virtual Reality?
- Virtual reality (VR) may be one of the most suitable technologies for rehabilitation
  - Motivating
  - Holistic environment
  - Risks safely simulated
  - Promotion of self-management

Virtual Reality – Serious Gaming Applications

- Initially, limited to recreation or motor rehabilitation using standard games
  - Clinical Example
- Rapidly developing serious gaming applications in SCI, stroke, PD, etc.
- However, evidence of VR in TBI and in cognitive rehabilitation is limited (Maggio et al., 2018)



Traumatic Brain Injury (TBI)

- A growing problem in New Zealand
  - 13% of the NZ population has experienced at least one TBI in their lifetime (Te Ao et al., 2015)
  - Common in wage-earning and child-bearing years of life
  - Second only to stroke for impact on employment and income
- Rehabilitation focused on ordinary life roles and opportunities
  - Challenges in fatigue, communication, balance, cognition, behavioural regulation, mental health, and relationships (Ponsford et al., 2014)
  - Social isolation is a major consequence; having the ability to practice critical skills in a safe space may be essential for increasing community participation

"*The issues of psychosocial adjustment and societal reintegration […] are usually more disabling than the residual physical deficits*"

Khan et al. (2016), p. 48

Traumatic Brain Injury (TBI)

- Fatigue is one of the most common symptoms after TBI, affecting up to 73% of individuals
  - Reported as the most troubling longer-term symptom in 43% of individuals
- Fatigue after TBI can be physically and/or cognitively based and can have a significant impact on function and wellbeing.
- It is poorly defined and the cognitive component of fatigue is often neglected in research and clinical practice (Shultz 2018).

Cognitive Fatigue

- Transient increase in mental exhaustion as a result of prolonged periods of cognitive activity
  - Subjective lack of mental energy perceived to interfere with activities
- However, many individuals following TBI have reduced awareness of cognitive fatigue.
- Reduced insight into declining mental energy, can lead to further harm, including risks of falls, and increased interference with social, work and community activities.

Difficult to Treat

- Treatments for cognitive fatigue (and other common TBI symptoms) include education, compensation, cognitive behavioural interventions, and/or mindfulness-based stress reduction (Khan & Amatya, 2018).
- However, treatment reliant on awareness
  - Requires experience in functional environments
- VR has advantages by allowing adaptability of the environment.
  - Complexity can be introduced as the individual progresses
  - Modification of real world stressors and hazards

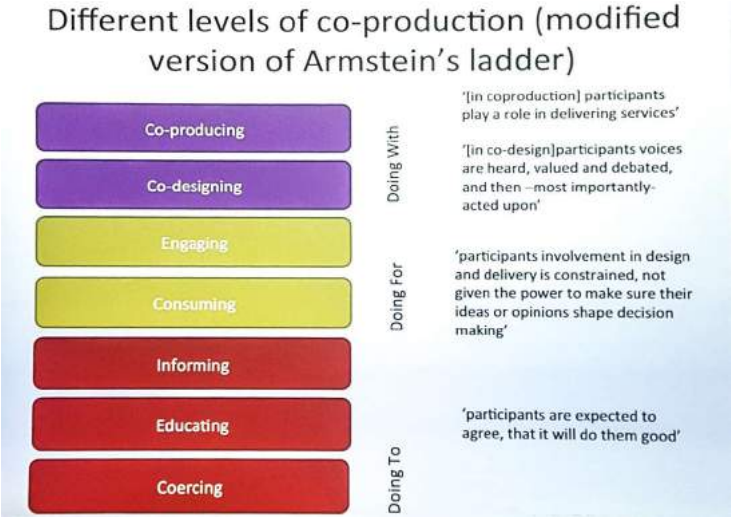
Evidence for cognitive rehabilitation using VR technology

- VR shown to be safe in TBI populations (Alashram et al., 2019)
- VR tools were shown to boost motivation by facilitating longer training sessions.
- The ability to tolerate longer sessions (more intensive rehab) could increase cortical activation, consistent with the principles of neural plasticity (Penn, Rose, & Johnson, 2009; Hanten et al., 2011; Kolk, 2018).

Limitations to Clinical Implementation

- Barriers include:
  - Overall cost and availability of tech/space
  - Limited evidence in non-motor domains
  - Limited generalisation to complex home and community environments.
  - Reduced clinician confidence in technology use
  - **Lack of end-user involvement in the emerging technologies**

Different levels of co-production (modified version of Armstein's ladder)



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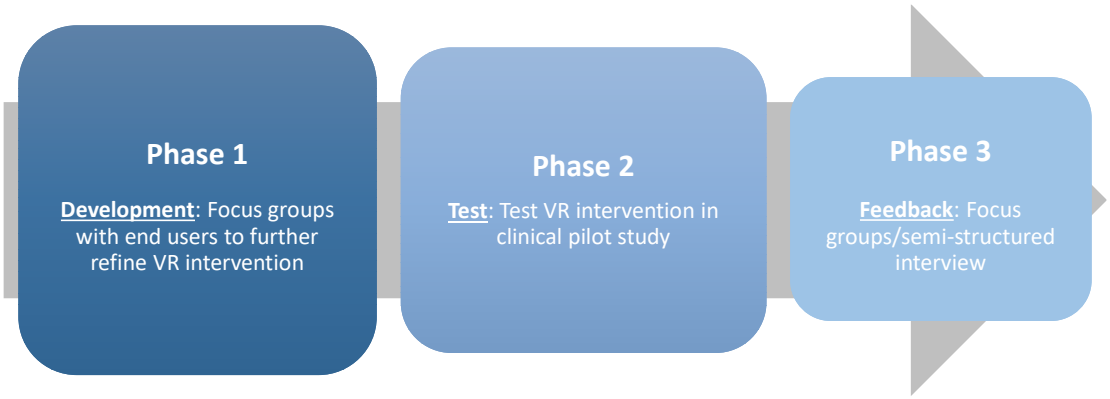
Aim

- A user-design feasibility study to develop and test a VR rehabilitation solution for TBI
  - Co-design in a translational manner
  - Sought perspectives of individuals with lived experience of TBI and experienced clinicians to guide all stages of the development and testing of the VR tool.

Project Outline



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Methods: Phase 1 - Development

1. Co-design focus groups with clinicians and individuals with lived experience of TBI
2. Collaboration with engineers, researchers and designers, influencing design iterations
3. Focus groups following trial of VR prototype

Participants

- Individuals with Lived Experience of TBI (*n* = 5)
  - 12 years post moderate-severe TBI (± 14.2 years) on average
    - Glasgow Coma Scale (GCS) score ≤ 12; Post-Traumatic Amnesia (PTA) duration > 24 hours
  - Aged 38.2 years (± 14.3 years) on average; 4 male
  - No longer in rehabilitation; all working part- (*n* = 2) or full-time (*n* = 3)
- Clinicians (*n* = 5)
  - Experienced in assessment and rehabilitation of TBI
  - Occupational Therapists, Speech-Language Therapist, Physiotherapist, Clinical Psychologist

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1st Co-design focus group

- Three focus groups
  - Trialed standard games and discussed possible applications of VR
  - Took turns trialling a "Google-Earth" programme, The Blue: An Underwater Experience, or a simple golf game
  - The participants in the group not wearing the VR headset were able to observe the VR projected images via a large screen

1st Co-design focus group

- Asked open-ended questions:
  - What they thought of VR
  - How it could be used in TBI rehabilitation
  - Their experiences with TBI and common symptoms
  - Requirements of a rehabilitation tool for these symptoms

1st Co-design focus group

- VR in this population was well tolerated
- Enthusiasm about the potential the technology could bring, but concern about the ability of individuals to use it

'It has to be something I would do when I've got a bit of energy ... But when I've got that fatigue crashing on me, the last thing I wanna do is put on a headset, fiddle with buttons'

Results: 1st Co-Design focus group

- Users desired realistic environment with focus on everyday tasks
  - Help translate gains in VR to real word activities
  - May make VR more acceptable to clinicians and those in rehabilitation
  - Suggestions included supermarket, airport, cafés and restaurants.

"Just practical tasks, practical situations … something that would reinforce ways for me to manage especially when I'm out and about, trying to be out and about, trying to be normal"

Results: 1st Co-Design focus group

- Both groups expressed early identification of cognitive fatigue could make treatment and acceptance easier

"It would just hit me, I would just crash, I've got it, I would feel like I'm just gonna die. It was just so powerful, it was like someone who's just cut my cord and boom, I'm gone."

'It almost felt like there was a fog covering, coming down over your brain and it's just like harder and sluggish.'

Results: 1st Co-Design focus group

- Agreement that complexity could be increased by creating a busier environment with people, noise, social situations and interruptions

"For me it's noise, that would really test me… People asking questions"

"On one side, someone nagging you, and then on the other side asking you questions […] while you're trying to do something"

"I don't know how you'd simulate it, but kind of like social interactions in general, where there's lots of people because obviously, like early on, I think that was probably quite tiring"

Results: 1st Co-Design focus group

- Feedback on tasks, level progression, outcome measures and clinical implementation
  - Both groups reported the system would be best in a therapy setting, rather than being used independently
  - Scoring or monitoring component was needed
  - Training in VR setup, use and troubleshooting was needed

'I think our clients really struggle to see their progress, so I think something like that would be really motivating'

'It's always good to have feedback 'cos you can always improve with feedback.'

Collaboration: Tool Development

- VR prototype environment based on a real-world café
- Focus on heightening awareness of limitations due to cognitive fatigue
- Distractions increased across each level
  - Visual (e.g., people walking by)
  - Auditory (e.g., ambient noise)

Collaboration: Tool Development

Domain	Levels 1 - 7
Short-Term Memory	Remember order for others at table
Long-Term Memory	Asking someone for a belonging that has been taken at the beginning
Visuospatial	Scanning menu for icons (e.g., gluten free icon)
Attention / Information Processing	Returning to conversation topic following distraction
Problem Solving	Paying bill (calculating total cost)
Metacognition	Comparison of self-ratings of fatigue before and after the game

Example of Level Progression

	Visual Distractions	Auditory Distractions
Level 1	• Only one other guest at the café, far off at another table, not moving much.	• Quiet café music, maybe the occasional coffee-machine sound
Level 7	• Guests at all tables close by to the player • People walking by to the counter • Animated gestures from people at the tables • Visual distractions (e.g. spilled food or line-up of people in the queue).	• Loudest café music • Regular chit-chat and regular bursts of louder noises (e.g., laughing) • Annoying mobile phone ringing • Regular café noises, baby crying or dog barking, • Repeated door opening chime, ambient outdoor noises (e.g., sirens, etc.)

Views of the Café

Communication Interactions

Ordering for Others at Table

Self-Ratings of Fatigue

Results: 2nd Co-Design focus group

- Participants tested the prototype in groups, watching each other before feedback

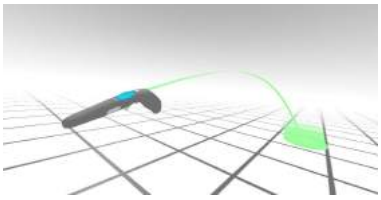
"*You put us in the exact right environment, this is exactly what happens when we're out*."

- Three themes were identified for future iterations:
  - Naturalness and ease of use of the VR system
  - Improving communication interactions
  - Troubleshooting clinical implementation

Naturalness and Ease of Use

- Participants without gaming experience and those with more serious impairments found the programme VR system difficult
- Benefitted from frequent assistance to manage the controls and unfamiliar processes such as teleportation and buttons

"Would be rough for someone using VR for the first time"



Communication Interactions

- To communicate, players chose one of four pre-written responses.
  - Did not reflect reality
  - Did not challenge their abilities
    - One of the most fatiguing aspects of community engagement.
  - Wanted more open-ended questions, with more natural interactions.
  - Talking out-loud was identified as a key aspect, rather than choosing from prepared response choices

"Conversation wears me out and I didn't have to say anything … My fatigue is only reflective of my output"

Clinical Implementation

- Clinicians indicated a desire for training:
  - Contraindications for use of VR in a TBI population?
  - How soon after an injury someone could use VR?
  - Ability to track outcome scores after game play
  - One-hour training session
  - Written instruction for set-up, use and troubleshooting of the VR system itself
  - Guidance on recommended dose and intensity

"I think it is an interesting concept; a creative way of working that has potential."

"Could be used as a graded exposure type activity and then build up to the real thing. I also think people who get overwhelmed with over stimulating social environments would totally benefit."

Next Steps

- Māori specific focus group with individuals following TBI and clinicians
  - Dr Johnny Bourke, Dr Emma Wyeth, Georgia McCarty, He Waka Tapu
- A pilot study in a clinical cohort
  - Focus groups will guide future modifications and barriers to uptake
- Possibility for widespread implementation
  - Application to further activities of daily living (e.g., groceries, driving, cooking)
  - Therapeutic mode
  - Support early intervention, assessment of skills and practice in populations unable to access community environments (e.g., Corrections)

Discussion

- This translational co-design approach is an advancement in VR gaming design
  - Incorporation of direct feedback from those with lived and clinical experience
  - VR well tolerated by clinicians and people with lived experience of TBI
  - Documented enthusiasm about the potential for this technology

Discussion

- Promising first steps
  - Safe environment where a person with TBI can test fatiguing community and social interactions without fear of embarrassment
  - Potential to provide accurate/simultaneous measurement of cognitive abilities during simulated functional tasks
- Identification of key requirements
  - VR tool requires a range of complexity and levels of support/instruction appropriate to individual's abilities
  - Purposeful clinical implementation indicated
    - Lack of time to learn about VR has been shown as a barrier for uptake (Glegg et al., 2014).

Discussion

- This intervention has enormous potential in TBI
  - Cognitive fatigue is one of the longest lasting and most debilitating symptoms of TBI
    - Can affect other cognitive and physical domains, such as memory, communication, attention, balance and executive functioning.
    - But, a notable lack of existing evidence-based rehabilitation approaches

"Traumatic brain injury is very isolating and you can lose confidence. You worry when you are rotting away at home, so this could be very helpful to get used to be around other people again"

Thank you!

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