Supplemental Material S4: Suggestions to Address Perceived Barriers and Risks Associated with Virtual Reality

Perceived barriers or risks identified by participants	Suggestions to address perceived barriers or risks
Patient	
Impacts of TBI on use of VR, including: • Upper limb impairments • Reduced mobility • Vision issues • Hearing issues • Cognitive and behavioral challenges • Tolerance of HMD (e.g., sensory issues, risk of overstimulation, fatigue)	• Provide VR experiences that do not require limb movements or use of hand controllers, or select apps/content that can be engaged with by using head or eye movements (VR3; SLP7) • Consider VR apps that can be used when seated (SLP7; VR2; VR3; Saredakis et al., 2020) – Some VR headsets and apps provide information about level of movement(s) enabled in the virtual environment (e.g., Oculus Comfort Ratings) • Determine if glasses or prescription lens inserts can be worn with the selected VR HMD (VR2) • Consider the signal-to-noise ratio and spatial audio design for hearing issues and if adding in background noises (VR2) • Observe and document if impairments impact on VR use (Birckhead et al., 2019) • Collaborate with multidisciplinary teams to consider appropriateness of VR use – including medical teams, psychologists (SLPs 7, 8, 10), occupational therapists or physical therapists (Bryant et al., 2020a; Madary & Metzinger, 2016) • Build up tolerance to VR over time (e.g., start with a few minutes of exposure then increase as time goes on; VR3; SLPs 7, 10) • Start with lower levels of simulation and progress to higher levels if tolerated (e.g., start with passive viewing of content → minor movement in virtual environment with hand controllers → flying/moving in virtual environment; VR3; SLP7) • Establish the length of time that can be spent in VR per patient to establish suitable dosage (SLP7)

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Potential for side effects of VR use	• Researchers/clinicians should view VR content prior to use with patients to determine possible issues and the potential for VR sickness (VR3) • Avoid or minimize use of virtual environments with flashing lights, white light, backlit light, blue waves, dynamic backgrounds, dual or triple axis head movements (VR3; authors) • Consider six degree-of-freedom movement rather than three degree-of-freedom movement (VR2) • Reduce the use of VR apps with gaming content (Saredakis et al., 2020) • Review VR content for any warnings for epileptic triggers (VR3) • Consider teleporting or third-person movements rather than gliding movements within virtual environments (VR2; Saredakis et al., 2020) • Consider clearance from treating medical team(s) regarding use of HMDs or for establishing patient suitability (SLPs 1, 4, 7, 8, 9, 10) • Consider apps that allow VR use while seated (SLP4; Saredakis et al., 2020) • Review HMD health and safety guidelines prior to use (authors) • If HMDs allow, adjust lenses for interpupillary distance (VR2; Saredakis et al., 2020) • Have a protocol in place for VR use, such as: - Ease patients into VR use (e.g., start with 5 min with a 10 min break before using again and do not use beyond 10 min at a time; authors) - Ensure patients are aware of low cybersickness risk and signs to look out for (authors) - Measure potential side effects by taking patient-reported measures (e.g., nausea, headaches, dizziness, anxiety; SLP7; VR2; VR3; Birckhead et al., 2019) - Consider taking patient observations before, during and/or after VR use (e.g., heart rate, blood pressure; VR1; VR2; SLP7) - Monitor patients when they are using VR and for up to 15 min post-VR use (VR3; SLP7) - Cease VR use and remove HMD immediately if symptoms of VR sickness are reported or observed (VR1; VR2)

Perceived barriers or risks identified by participants	Suggestions to address perceived barriers or risks
Impact of VR use on people with history of trauma or anxiety	• Screen VR content prior to use for potential triggers (e.g., avoid horror games to reduce the potential for stress and anxiety; VR3) • Screen patients prior to use (e.g., be aware of a history of psychology or mental health input) and consider psychology/medical input (SLP7); gathering case history around appropriate stimulus (SLP4) • Consider monitoring patients when using VR if they have potential for anxiety (e.g., heart rate, blood pressure; SLP7; VR2) • Clearly explain what will happen when using VR (e.g., "You are going to enter a virtual world and you are safe. I am here to help, and I will observe you the whole time"; VR2; Madary & Metzinger, 2016)
Patients may want to use VR more than it can be offered Will VR take away from other therapies or rehabilitation goals	• Use VR to supplement current therapies rather than being a replacement (e.g., offer one week on, and one week off; SLP7) • Provide clear expectations to patients and their families/carers about frequency and aims of VR use (SLP7) and its capabilities (e.g., not a "cure"; SLP8; Bryant et al., 2020a; Madary & Metzinger, 2016) • Have a clear purpose for using VR and place this in the context of rehabilitation priorities (SLP7; Bryant et al., 2020b) • Consider VR use in context of evidenced-based practice and clinical judgement (SLPs 1, 8, 9, 11)
Ability to use VR independently or remotely	• Provide adequate training for patients with TBI and their family/carers/support workers (SLPs 2, 6, 10; Bryant et al., 2020b; Vaezipour et al., 2022) • Target family, carers, and/or support workers who are interested in technology to facilitate buy-in and support use (SLPs 2, 6, 10)
Clinician	
Clinician knowledge of VR, skill in using VR, and attitudes towards VR	• Evidence should evolve to establish guidelines/protocols relating to (SLPs 4, 8, 9, 10, 12, VR3; Vaezipour et al., 2022): - Pre-assessments for VR suitability - When it is suitable to commence in rehabilitation journey - Specific impairments or conditions that may be associated with increased risks/could prohibit VR use (e.g., epilepsy, visual issues, motor impairments)

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	- What applications and tasks may be suitable for use with people with a TBI (VR3) • Support clinicians with gaining knowledge and skills in using VR (VR2; VR3; SLPs 1, 2, 5, 6, 7, 9, 11, 12, 13, 14; Bryant et al., 2020b; Glegg & Levac, 2018; Vaezipour et al., 2022) - E.g., workshops, online courses, trials before implementing clear and easy instructions - Provide continued training and support • Consider participant matching and trials before purchase (SLPs 5, 6; Vaezipour et al., 2022) • Promote and encourage VR use to establish buy-in (e.g., video demonstrations, having "VR champions"; SLPs 6, 10)
Ethics and privacy	
Ethical considerations • Avatar bonding • Ability to provide consent and is there need for ongoing consent to be given • Comprehension of VR and being in a virtual environment	• Only use VR with patients who can provide informed consent (Madary & Metzinger, 2016) • VR environments should be designed or selected to reflect real-world experiences (Bryant et al., 2020a) • Consider measures of temporal perception (VR3) • Determine the level of realism that works for each patient and allows them to differentiate between VR and the real world (e.g., real-life videos versus hyper surreal VR apps or content; VR3) • Remind VR users that they have provided consent throughout their VR experience (Madary & Metzinger, 2016)
Privacy	• Review VR apps for log-in requirements (e.g., are personal details required) and potential for access to public content (i.e., ability to interact with strangers in a VR app), and ensure appropriate privacy and access restrictions are in place (VR2; SLP8) • If exposure to harm or issues in non-private apps, stop the VR experience by removing the HMD and turning it off (Bryant et al., 2020a).
Organisational	
Wi-Fi access and firewalls	• Consider workplace firewalls, Wi-Fi availability, and restrictions on website access (SLPs 2, 8, 14) • Consider deployment of 4G or 5G hotspots for Wi-Fi access (VR2)

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Workplace and organisational support and requirements	• Ensure that procedures are followed for gaining site approval if required (e.g., ethical clearance, biomedical engineering procedures, clinical governance, engaging with stakeholders; SLP9) • Ensure that ICT support is available (SLP8)
Access to funding and purchasing VR	• Advocate on discharge through funding sources (SLP4) • Consider multidisciplinary VR applications and uses (SLPs 1, 6, 8, 9, 10) • Consider VR deployment and the associated logistical challenges that may arise (e.g., access to Wi-Fi, in-home versus clinic use; VR2) • Consider AAC models for VR access and implementation (e.g., trial before purchasing, workplace training; SLPs 5, 6)
Virtual reality logistics	
Sterilisation and cleaning of hardware	• Use guidelines for cleaning and disinfecting VR devices (VR1; VR2; VR3; Moore et al., 2021) • Use rigid plastics or HMD inserts that are wipeable (VR2; VR3; Moore et al., 2021) • Some facilities may implement quarantine of VR devices (VR2)
Environmental risks (e.g., risk of tripping on wires, adequate space)	• Consider wireless HMDs (VR2) • Consider VR apps that can be used when seated (SLP7; authors) • Draw guardian boundaries (i.e., a 'space' is drawn within the VR headset, and a warning is given when the VR user approaches the boundary; VR2) • Ensure VR space is large enough to avoid hitting objects, furniture, walls etc. (SLP12) • Observe patients when using VR (SLP12)

Note. TBI = traumatic brain injury; VR = virtual reality; HMD = head-mounted display; SLP = speech-language pathologist; ICT = information and communications technology. Suggestions were provided by the participants in this study, the authors, and relevant literature. Reference to the SLP and VR specialist participants in this study is indicated by SLP and VR followed by participant number (e.g., SLP1, VR1).

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