RESEARCH-ARTICLE

Modelling Patient-Therapist Collaboration for Brain Injury Rehabilitation in Virtual Reality

STEPHANIE ELENA CROWE, University of Canterbury, Christchurch, CAN, New Zealand

BAHAREH SHAHRI, University of Canterbury, Christchurch, CAN, New Zealand

THAMMATHIP PIUMSOMBOON, University of Canterbury, Christchurch, CAN, New Zealand

SIMON HOERMANN, University of Canterbury, Christchurch, CAN, New Zealand

ANNALU WALLER, University of Dundee, Dundee, Scotland, U.K.

Open Access Support provided by:

University of Dundee

University of Canterbury

Published: 28 June 2024

UMAP '24: 32nd ACM Conference on User Modeling, Adaptation and Personalization
July 1 - 4, 2024
Cagliari, Italy

Conference Sponsors:
SIGCHI
SIGWEB

https://doi.org/10.1145/3631700.3665239
ISBN: 9798400704666

Modelling Patient-Therapist Collaboration for Brain Injury Rehabilitation in Virtual Reality

Stephanie E. Crowe*
stephanie.crowe@pg.canterbury.ac.nz
University of Canterbury
Chrichurch, New Zealand

Bahareh Shahri
bahareh.shahri@canterbury.ac.nz
University of Canterbury
Chrichurch, New Zealand

Thammathip Piumsomboon
tham.piumsomboon@canterbury.ac.nz
University of Canterbury
Chrichurch, New Zealand

Simon Hoermann
simon.hoermann@canterbury.ac.nz
University of Canterbury
Chrichurch, New Zealand

Annalu Waller
a.waller@dundee.ac.uk
University of Dundee
Dundee, United Kingdom

ABSTRACT

In the era of digital transformation, the utilisation of Virtual Reality (VR) applications in brain injury rehabilitation presents a novel frontier with vast potential. However, concerns persist about how traditional communication pathways between therapists and patients can be transformed into digital equivalents. Immersive virtual reality submerses patients in a virtual world, with therapists taking the role of external spectators. This has implications for the therapeutic alliance (TA), which is based on interpersonal bonds and effective communication between therapist and patient. This study investigated the use of immersive VR in clinical settings for the rehabilitation of acquired brain injury (ABI). The aim was to understand how to design a smart virtual therapeutic system that can be adapted to various needs of patients and therapists during the intervention. Through observation and semi-structured interviews, patient-therapist interactions were analysed during VR-assisted and traditional rehabilitation sessions, revealing challenges related to effective collaboration. Findings indicated changes in interaction and communication with the introduction of VR: informal dialogue decreased, while shared laughter and therapist feedback increased. Despite the visual disconnect imposed by VR headsets, therapists continued to use guiding gestures and engaged with patients. Interviews highlighted the importance therapists place on rapport-building, and both relied on each other for expertise and reassurance. This research offers valuable insights into the potential to transit, transform and enhance traditional rehabilitation practices with the use of virtual reality and suggests avenues for human-centred design of VR applications tailored to ABI rehabilitation and TA, ultimately enhancing therapeutic outcomes in this domain.

UMAP Adjunct '24, July 01–04, 2024, Cagliari, Italy

ACM ISBN 979-8-4007-0466-6/24/07
https://doi.org/10.1145/3631700.3665239

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Empirical studies in collaborative and social computing**; **Empirical studies in HCI**; **Computer supported cooperative work**; **Empirical studies in HCI**.

KEYWORDS

virtual reality, brain injury rehabilitation, therapeutic alliance, patient-therapist interaction

ACM Reference Format:
Stephanie E. Crowe, Bahareh Shahri, Thammathip Piumsomboon, Simon Hoermann, and Annalu Waller. 2024. Modelling Patient-Therapist Collaboration for Brain Injury Rehabilitation in Virtual Reality. In *Adjunct Proceedings of the 32nd ACM Conference on User Modeling, Adaptation and Personalization (UMAP Adjunct '24), July 01–04, 2024, Cagliari, Italy.* ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3631700.3665239

1 INTRODUCTION

Acquired brain injury (ABI), including stroke and traumatic brain injury (TBI), is one of the most common causes of disability and death in adults around the world. Rehabilitation for ABI is important for recovery and often includes activities that focus on regaining skills for everyday activities, training motor and cognitive functions, and are performed primarily by occupational therapists (OT) who support relearning of everyday tasks.

The relationship and collaborative working alliance between a patient and a therapist is key in determining the success of occupational therapy [15, 32, 35], with therapists playing a vital role in maintaining patient engagement during rehabilitation [38, 40]. This working relationship and connection between patient and therapist is an important factor in the therapeutic experience of a patient, with research stating that "It is not enough to give a patient something to do with his hands. You must reach for the heart as well as the hands. It's the heart that really does the healing" [12, p. 249]

This patient-therapist working relationship, often referred to as the therapeutic alliance (TA) or working alliance, is primarily explored in psychotherapy [18]. The origins of TA can be traced back to Freud's theory of transference and counter-transference [8], with TA now mostly understood through the lens of Bordin's theory [14]. Bordin states that the TA is determined by three factors; the patient and therapist's agreement on tasks, agreement

on goals, and the interpersonal bond between them. Originating in psychotherapy, Bordin explains that this theory can be applied to all change situations regardless of the treatment modality. A favourable therapeutic alliance in motor rehabilitation has been shown to improve therapy effectiveness, leading to sustained benefits, including the ability of patients to maintain employment after rehabilitation [19, 31], with [12] also highlighting its importance for personal connection and collaboration.

Virtual reality (VR) is becoming increasingly popular in therapeutic settings due to increased affordability, as evidenced by the increase in research in the area. A recent Cochrane review included 72 studies investigating the effectiveness of VR for people in stroke rehabilitation [22], increasing from only 19 studies in 2011 [21] to 37 studies in 2015 [20]. More recently, in 2023, a review by [10] found that VR rehabilitation for stroke was superior, with or without conventional therapy over conventional therapy, for upper limb. Also, a review from [5] found that the immersive nature of VR improves patient engagement and motivation. In recent years, several VR interventions have been designed for the rehabilitation of people with an ABI with a focus on retraining of daily activities, helping patients recover their upper limb function and gait and balance [6], and also to improve their cognitive function [25]. With this increase in use, it is highlighted that standardised operating procedures for VR in physical rehabilitation are critical to its success [24].

In stroke rehabilitation, patients perceive the quality of the client-therapist partnership to be of primary importance [29]. Therefore, with the current digital transformation in healthcare, including the introduction of VR technologies, there are still questions about how the use of VR affects this partnership. In a systematic review by [30], studies investigating the association of verbal and non-verbal communication using TA constructs were found to be scarce. Hence, we gain novel insights by investigating this topic, as it is important to understand how the introduction of VR alters rehabilitation practices in a clinical context and how we can ensure that VR systems are designed taking into account the interaction and alliance between the patient and the therapist. In this research, we ask: "What are the key differences in interaction, collaboration, and alliance between immersive VR therapy for ABI rehabilitation and real-world ABI rehabilitation?" and "What attributes of the therapeutic alliance are important to include in a VR system for ABI rehabilitation to ensure effective interaction, collaboration, and alliance?".

2 RELATED WORK

Although much of the theory centres around Bordin and has psychotherapeutic origins, recent research has defined TA in occupational therapy as "a trusting connection and rapport established between the therapist and the client through collaboration, communication, therapist empathy and mutual respect' [15]. TA is shown to be a multifaceted interplay of technical skill, communicative competence, and the reflective capacity of the therapist to respond and feed-back to the patient at the time of therapy. In a review from [9] it was found that agreement on goals was the most reported aspect of congruence, friendliness the most reported characteristic of connectedness and clarity of information, active listening, and non-verbal skills as the most represented factors of communication. Mutual understanding and active involvement were highlighted as the most important characteristics of partnership and the roles and responsibilities highlighted by the therapist's ability to activate patient resources and motivate and encourage them.

2.1 Patient-Therapist Bond

A focal area of Bordin's theory [14], is the interpersonal bond between the patient and therapist. The formation of this bond, often includes the building of rapport and gaining the trust of patients during rehabilitation. This can be done by acting in a caring and professional manner, while also treating the patients with empathy and respect, building a healthy therapeutic environment. [23]. In a study by [13] a key theme of the TA was personal connection, including bonding and humour as key components. The patient-therapist bond was found to thrive when the therapist shared personal information such as an adverse event, expressing their views and emotions to the patient, and sharing information about their family and what they did on the weekend. This exchange, or kōrero as described by a participating patient, stood out as a way to gauge their relationship and build rapport. In addition, they found that shared humour was appreciated by several patients, as it seemed to provide hope to those who needed it. These kinds of personal and humorous interactions can break down perceived barriers between the expert and the patient.

2.2 Communicative Success

Effective therapist-patient communication is vital for rehabilitation success, encompassing verbal and non-verbal cues. Recent studies on interactions in real world settings show that therapists frequently use verbal communication to instruct patients [34], and are considerate when giving feedback on performance [26]. Research by [3] and [17] highlights the importance of communication strategies in therapist training, which helps develop the Therapeutic Alliance (TA). In addition, it is vital for the therapists to have casual conversations during therapy sessions, discussing the patient's personal life, worries and aspirations. Such informal interactions position the therapist as an equal partner in power dynamic, fostering rapport, cooperation.

In addition, in the TA, a key function of the therapist as a communicator is to provide feedback to patients during rehabilitation. Therapists may use verbal, physical, or visual cues to aid in learning. Studies show that verbal feedback, designed to motivate patients, significantly improves their task performance and endurance. Further, verbal encouragement has been shown to improve performance in motor endurance tasks [11], [36], underscoring the need for ongoing dialogue and reflective negotiation between the patient and therapist. With the rapid progression of VR in rehabilitation, it is crucial to grasp its application and how we can leverage evolving technology to foster a positive TA. In addition, there is emerging research on virtual therapists, with a recent review by [16] finding that virtual therapists are currently only used to guide patients and provide visual, haptic, and audio feedback. It also highlighted that more research is needed in this area, with, at the time of the review, only seven articles/studies investigating the topic.

3 METHODS

This study took a human-centred approach and used qualitative observations and interviews to gain insight into how interactions between patients and therapists differ with or without VR use in rehabilitation sessions. The study was carried out in a hospital in Scotland, UK, observing routine occupational therapy rehabilitation sessions. Ethical approval was sought from both the University of Canterbury and the Tayside National Health Service (NHS). In the non-VR sessions participants carried out tasks in a kitchen, whereas, in the VR setting the patient wore a head-mounted display (HMD) and did not see the real world, whilst the therapists could see the patient and observe the virtual environment (VE) via an iPad. We used naturalistic observation [7] (observing subjects in their natural environment without intervention) and semi-structured interviews [4], to understand how patients and OTs adapt their interaction between settings.

3.1 Participants

Five patients and five therapists participated, in pairs. Therapist criteria included being qualified occupational therapists or occupational therapy technical instructors. Patients were 18 or older, English speaking, able to consent, and in any recovery stage. Exclusion criteria included specific medical conditions with a history of seizures, cerebellar injury, or diplopia/psychology, or significant communication difficulties. Three patient participants had previous experience using VR, two had no experience. All therapists had previous experience using VR in their practice. Four pairs had an established therapeutic relationship.

3.2 Materials and Apparatus

Research was carried out in a hospital setting. The HMD used by the participants was the Oculus Quest (Meta, 2019). Cameras were strategically placed to achieve a multi-perspective view of the recorded observations and audio was recorded using DJI wireless lavalier microphones, model AST01 [1]. Video analysis was carried out with Adobe Premiere Pro 2023 Version 23.3.0 [2]. Transcriptions were produced using this software, faces blurred, and episodes of interest extracted. All participants played the VR game 'First Steps' and in the kitchen setting all participants made tea and toast. Both activities were at the OTs discretion in accordance with the patient's rehabilitation goals; in the VR session the therapist also used an iPad to view the patient's perspective in VR.

3.3 Procedure

Patient and therapist pairs were first observed in two settings, VR and a non-VR. Immediately afterward, participants were individually interviewed to ask about their experience. Extensive notes were taken throughout to supplement session recordings and the overall time spent with participants ranged from 44-130 minutes, including taking consent.

3.3.1 Observations. In the first stage of the study, the researcher made two observations per patient-OT pair. The first rehabilitation session observed was that of a patient and OT taking part in a routine non-VR rehabilitation session where they performed a meal preparation task. The time spent doing the non-VR activity ranged from six to 11 minutes. The second observation witnessed the patient and the OT participating in routine VR rehabilitation. The VR activity time ranged from 13 to 41 minutes. The researcher did not interfere whilst the participants performed tasks and purely observed the interaction behaviours between the pairs during the rehabilitative tasks. Observations were tasks and activities that would be performed routinely in a therapy session, the researcher did not ask them to perform additional tasks.

3.3.2 Interviews. A semi-structured interview was conducted with each participant after observation, each interview taking 20 to 40 minutes. After participants were observed in both settings, they participated in a semi-structured interview to better understand their experience. In interviews with both patient participants and OT participants, they were asked how their experience of using VR in rehabilitation was, how they found setting up, what difference they felt between physical and virtual settings, and how the introduction of VR may have affected their ability to communicate and interact. This was around 20 minutes long.

3.4 Analysis

First, both audio and video recordings were analysed using Discourse Analysis, specifically, Conversation Analysis (CA) [28]. The recorded video data of sessions was repeatedly watched, and a log of pertinent moments was made for each recording thereafter. This initial stage provided an early understanding of the entire data set and allowed the extraction of episodes of interest and the identification of analytic themes. The initial collections contained episodes, sometimes called 'noticings' [28], which struck the researcher as relevant almost immediately, and were supplemented with interview data. The audio recordings of the interviews were transcribed and analysed using Interpretative Phenomenological Analysis (IPA) [33] to identify themes. The general themes were identified across both observations and interviews.

4 RESULTS

The result of the analysis is categorised under three main themes, presented in Table I.

Themes	Sub-themes
Communication and Supportive Action	Verbal Instruction and Feedback
	Gestural Guidance
	Active Involvement
Cooperative Partnership and Reliance	Dependence and Safety
	Technological Readiness
	Rapport and Empathy
Connectedness	Formality of Conversation
	Distance and Disconnect
	Humorous Moments with Shared Laughter

4.1 Communication and Supportive Action

4.1.1 Verbal Instructions and Feedback. The therapist participants were found to need to use more verbal instruction and feedback in the VR therapeutic sessions compared to their regular therapeutic session. With one therapist saying *"Verbally I had to communicate*

a lot more." (T5). Furthermore, another therapist compared the rehabilitation settings by commenting *"In the kitchen they can see you and you can gesture whereas in the VR, when you've got the VR HMD on, it's a lot of verbal [communication] "* (T3). It was also observed that both the patient and the therapist relied heavily on verbal communication during the VR sessions, as the patient could not see the therapist. In contrast, while there was significant verbal interaction in the kitchen setting, it mainly consisted of casual discussions about everyday life, unlike the directive nature of the communication in the VR sessions.

An interesting point was raised regarding technology limitations and its use with brain injured patients, with one participant noting delays in therapists being able to see what the patient sees in real time, he said *"There is obviously a little bit of a delay in when you're speaking to them and what you can see on the casting versus what they can see"* (T4). They added a point on the effects of a brain injury and how that could impact verbal communication, where there is a heavy reliance on it in VR sessions, *"If it was somebody that maybe had decreased processing, there would be more of a delay. And I think it's just being able to give them that time like you would with any other task"* (T4). In the Kitchen tasks, therapists can use a multitude of different communication techniques, from verbal, facial expressions, and gestural, and it was found that by the patient wearing a HMD for VR, communication reduces to only verbal. However, therapists continued to provide gestural guidance even when the patient could not see them (see Figure 1).

Figure 1: Therapist gesturing to the patient for instruction. Left image shows the therapist demonstrating to the patient what to do, right image shows the therapist pointing something out to the patient.

4.1.2 Active Involvement. In one instance, a patient with weakness on the left side prompted the therapist to take control of the left controller during VR activities, resulting in a collaborative play with the therapist describing it as *"he was shooting my hand, but also he was moving the fingers and watching the fingers move when he was dancing."* (T5). A patient also clarified that having the therapist in the VE with them would be beneficial, declaring *"I think it would be good if the OT had had one as well and we could both do it together, and then ... You don't feel so alone in the little VR thing."* (P3)

When asked about potential interruptions caused by technological issues and their impact on the therapeutic relationship, a patient emphasised *"I think you'd still be developing a relationship because it takes a fair bit of time just getting it started and sorted... and you've got that voice there just reassuring you."* (P5). Similarly, a therapist said *"I think it's kind of working together and almost both being a little bit blind to the environment."* (T1)

4.1.3 Rapport and Empathy. In their cooperative partnership and reliance on each other, it was important that the pair established rapport, with an empathetic approach often taken by the therapist. Therapists expressed differing opinions about the role of VR in building relationships with new or existing patients with whom they have established rapport. It was said that *"I think at this stage that would be a bit more challenging if you were someone who didn't know the patient so well"* (T1), though opposing, it was also stated that *" ... if we're struggling to get that kind of therapeutic connection with them... bringing them in here and doing something a bit different I think would help potentially break down some of those barriers"* (T4). Therapists shared thoughts such as *" ...integrating a more relaxed approach and allowing [them] to do something they enjoy does encourage good rapport with the patients"* (T2) and *"I wanted her to have fun with it. I wanted her to be happy that if I wanted to bring that [VR HMD] back out with her, then she would be excited to use it again"* (T5)

4.2 Connectedness

Connectedness is a component of the overall bond between the therapist and the patient, with an emphasis on the quality of their communication. Connectivity differed between different environments. In the non-VR setting, patients and therapists chatted informally about daily life and family, whereas this was not present in the VR setting. In addition, therapists often sat farther away from the patients when VR was introduced compared to the kitchen setting. However, positively, they exhibited increased episodes of laughter and sharing humorous remarks with each other.

4.2.1 Formality of Conversation. Communication is key to TA, and one patient observed that to get better, they must communicate well with their therapist, they said *"I communicate quite well with them. I'm here for a reason and that's to get better... And part of that is speaking to the OT"* (P1). However, a contrast was found in the way the conversation was structured in each setting. The kitchen setting facilitated informal conversation between the two, but once VR was introduced, informal conversation diminished and talk about progress increased. Generally, in the non-VR setting, less verbal instruction was given; however, therapists gave instruction and guided the patient in the VR setting. When VR was introduced, the focus shifted to focusing on the stimuli in the VR environment, and the therapist focused on the iPad ready to give instruction.

This contrast was also noticed by the participants, one patient stating *"Obviously I think in the other setting [kitchen] you would get more [chat] because the OT and I joked and blethered ...and it just puts you at your ease a bit more"* (P5). One therapist shared that they needed to give more instruction during VR use, which hindered their ability for informal chat *"...we could have that more natural chat. Whereas in the VR ...I am kind of dictating a little bit and being very much the therapist and very much the patient"* (T3), adding *"...in the kitchen I would kind of take a bit more of a step back and kind of let her get on with it while having a conversation, just a sort of informal chat about things."* (T3).

This contrast was clear from the observations, and the therapists felt that the use of VR in rehabilitation created a more relaxed environment for their dialogue, stating *"...it allows you to speak about stuff, more stuff that they enjoy. It's less intense sometimes than when you're sat down with a patient moving their arm or getting them to write things."* (T2). Observations also highlighted the insufficient time allocated for discussions about goals and objectives at the beginning and end of VR sessions, with therapists saying *"you might need to before or after VR session, have that information gathering. ... I wouldn't feel comfortable and I don't think you maybe should, in the middle of dancing with a robot, ask if she's had any sensation issues or anything..."* (T3). One patient said *"I wouldn't imagine going into a room all the time. "Hi. Sit down, do that." and then out"* (P5),

4.2.2 Distance and Disconnect. Disconnect was also observed between the patient and therapist. This was mainly due to the level of immersion the patient had in the VE, stating *"You're in your own world. You're not with the therapist. The therapist is not in your field of vision. So, you know, essentially, you could be anywhere"* (P1) and *"I wasn't aware of them being there, I just knew that he was there."* (P5). In addition, therapists often sat or stood a distance from the patient in VR sessions; however, in non-VR the therapists were often seen standing closer to the patient and supporting them when necessary. In addition, the therapist in the VR sessions used an iPad to see what the patient sees in the VE. In observations, it was clear that this was a distraction, with therapists often staring at the iPad for long periods and rarely looking up to see the patient.

Some patients were looking for a connection with the therapist, often seeking their reaction to something they did, a patient said *"Because you can't actually see the other person, obviously, it's a bit harder. You can't see how they react to things"* (P2). Both often expressed frustration with the inability to be in sync and understand what is happening with the other person. One patient expressed this frustration saying *"She [OT] is just sitting there going "it's OK, just press the button" and I'm like "arggh""* (P3), displaying a disconnect between the therapist giving instruction but unable to show the patient what they mean, or supporting them properly since they only see the patients' viewpoint through the iPad.

4.2.3 Humorous Moments with Shared Laughter. During observations, it was clear that using VR in rehabilitation instigated more moments of laughter between the pair than in the non-VR setting, with one patient stating *"It was two totally different functions. You know, one's a practical function and one's a bit of fun"* (P1). The researcher also noticed that the patient would often outperform in VR and hoped for a response from the therapist if it was deemed funny. These moments would arise when, for example, the patient would use an item beyond its normal function in the real world, with one patient sharing *"I wouldn't be so worried about scolding or dropping or, you know, breaking it, whereas it's because I would still know it's a game but that might have helped me to bring that hand in"* (P5), also highlighting that this ability could benefit their rehabilitation.

In addition, the virtual objects themselves frequently prompted laughter, such as the patient controlling a remote control ship into other virtual objects, dancing with a virtual character, and generally using objects in an unexpected way. P2 spoke to this, highlighting that the objects teleported in and the throwable objects were there different to the non-VR in a fun way, they said *"Things can literally just teleport in, it encourages you to scan quite a bit because it's like you never know what was going to change when you look away"* contrasting this with real life, saying *"Whereas in real life, obviously you have a fairly good idea of if things can possibly change."* (P2). They added *"There are less things to throw around in the physical space. There weren't paper aeroplanes that appear on the tabletop"* (P2).

5 DISCUSSION

In this research, we asked, *what are the key differences in interaction and collaboration between immersive VR therapy for ABI rehabilitation and real-world ABI rehabilitation?* and *What attributes of the therapeutic alliance are important to include in a VR system for ABI rehabilitation to ensure effective interaction and collaboration?*. The findings have highlighted the contrasts between the patient and the therapist interaction when VR is used in rehabilitation versus a non-VR rehabilitation setting. These differences have been themed and have pinpointed areas of interest between the shared bonds between pairs, their communication style (including the use of humour), their connection, and the delivery of feedback and guidance to patients.

The first set of findings drew on themes of bond, with therapists quoted saying "we're in this together" and labelling the patient-therapist relationship a "partnership" when recalling their experience of using VR. Often referring to this partnership when moments of technological error occur, possibly strengthening the bond rather than breaking it as might be assumed. Furthermore, one session exhibited combined play when using VR, where the therapist used one controller, resulting in them unintentionally playing together in VR. This point was emphasized by another participant who would have liked the therapist to be in the VE with them. This idea of bond as part of the TA aligns with the literature of [9], which lists connectedness and partnership as key attributes of the TA. They also found in their review that active involvement from the therapist was important.

Regarding patient-therapist communication, the findings showed a clear difference in how the pair communicated in each setting. The non-VR setting gave space for informal conversation between them, often asking about one another's family and home life. This aligns with the research of [13] who found that the patient-therapist bond can thrive when the therapist shares personal information. In addition, the findings of [39] reinforce this and convey that an equal conversation partner is positive for rapport building and cooperation. When VR was introduced, informal conversation decreased, replaced by instruction and performance feedback. Therapists often focused on an iPad to view patients' perspectives, shifting dialogue toward guiding them in an unfamiliar environment.

Part of successful communication in rehabilitation also includes humour and laughter [13]. This was observed in the VR session but less frequently in the non-VR setting. Positively, the technical difficulties experienced, the VE presented to the patient, and the tasks and objects in the environment all contributed to this shared laughter between the patient and the therapist. In particular, patients had fun interacting with objects that were out of the ordinary and functioned in an unrealistic way, such as throwing

something and it suddenly reappearing again beside them. Humour can be used to break through perceived barriers in the therapeutic relationship and, as highlighted by [13] it is a key contributor to therapeutic bond. Similarly, introducing VR led to a disconnect; while in the kitchen, patients could easily gauge the reactions of the therapists, this was lost with an HMD. Despite this, patients still sought the reaction of the therapist, occasionally becoming frustrated when unable to convey actions or observations in the virtual environment.

Finally, in the traditional kitchen setting, verbal instructions were rarely necessary for patients engaged in routine activities, leading to predominantly casual conversations. Occasionally, therapists would check if patients needed assistance. In contrast, during VR sessions, the therapists provided significantly more verbal guidance and continual encouragement. Therapists recognised the need for increased verbal interaction, often because they could not use gestures or offer physical assistance as they might in a kitchen, for example, helping lift something. This dependence on verbal instructions can pose challenges for patients with brain injuries who suffer from aphasia, affecting their speech comprehension. Despite patients being unable to see the real world, therapists persistently employed non-verbal cues, such as pointing or showing how to perform a task.

5.1 Design Recommendations

The findings have shown that when VR is introduced into the rehabilitation setting, it alters the patient-therapist interaction, having an impact on elements of the therapeutic alliance. It is therefore advised that any future design facilitates this interaction and allows for collaboration, reducing the 'barrier' between the pair. This 'barrier' of the patient wearing a head-mounted display currently eliminates any eye contact, precludes the patient from seeing any gestural guidance from the therapist, and can cause disruption and confusion when it does not work as expected.

It is envisioned that to reduce this barrier and make a more accessible system, the therapist should be translated into the virtual environment, allowing them to show gestures through a virtual avatar and to have any level of involvement necessary in the VE. A previous systematic review from [16] emphasises that the use of virtual therapists for motor rehabilitation is in its infancy. This could be done by developing a VR system that allows for multiplayer co-location, meaning that the patient and therapist can both wear VR headsets, be in the same room but also be co-located in the virtual environment. This would allow them to interact in a way that supports the therapeutic alliance. It would also be beneficial to use technology such as Quest 3, which supports pass-through, allowing the therapist to safely see the patient in the real world whilst seeing what the patient sees in the fully immersive environment. Previous research from [37] has shown that using pass-through systems, such as Multi-channel Dynamic Immersion (MDI), supports a better transition between VR and real-world tasks, meaning that therapists could more easily work across both the real world and the virtual environment.

We think it would be beneficial to have a VR system designed that allows the therapist to interact with the same objects in the VE as the patient while still seeing them for safety. It is imagined that by seeing the patient's VE and the real world, the therapist will be less likely to distance themselves from the patient and interact with them, supporting a bond and their therapeutic alliance. This will also create an opportunity for co-playing. The systems should also account for the beneficial conversation between the patient and the therapist, especially at the beginning and end of the sessions to discuss tasks, aims, and progress.

Lastly, the findings showed that it is important for the patient to see virtual reality in rehabilitation as something different from the norm and fun, enticing them to continue using it and reducing any fear of technology. With this in mind, it is advised that the virtual environment design should be visually exciting, but within limits for brain-injured patients, and have activities that can be altered in use depending on the therapy tasks and goals. Specific elements mentioned in this research include re-spawning objects, activities encouraging visual scanning and items or activities that would not be seen or done in the real world, and importantly something to encourage shared laughter.

5.2 Limitations and Future Research

With regard to methods, it can be challenging to interview brain-injured patients due to the effects of their injuries [27]. Future research should factor this in and use alternative methods to interview directly after observations, such as email interviewing or retrospective methods. Furthermore, due to ethical restrictions, we were unable to see patient notes and, therefore, were unaware of the brain injury suffered by the patient. We were also unable to control for the experience of VR participants and whether the patient-therapist relationship was already established or new. Future research should explore the use of VR and its effects on TA for a longer period of time and with several sessions. Research should also continue to seek the input of the patient and therapist on the design with co-design methods.

6 CONCLUSION

This research explored VR's role in the digital transformation of rehabilitation for acquired brain injuries, focusing on its impact on the therapeutic alliance. It investigated how traditional therapist-patient communication can be translated into digital equivalents and how VR systems can adapt to the needs of patients and therapists.

It was found that when VR is used in a therapeutic setting, the therapists take on the role of an external spectator, since the patient wearing the headset is fully immersed. Although communication, both verbal and non-verbal, was found to be crucial, challenges were noted in conveying non-verbal cues within VR setups. Furthermore, the cooperative partnership between the patient and the therapist, essential for rapport, was influenced by technical capabilities, resulting in moments of humour but also affecting the overall experience. Nevertheless, VR fostered shared laughter, enhancing connectedness despite the absence of informal conversation and physical closeness that is common in non-VR sessions.

Considering communication, partnership, and connectedness is vital in designing effective VR systems for effective rehabilitation. This research helps us better understand target users based on their characteristics, needs, preferences, and behaviours, using user

modelling to predict how different users will use the VR system and to help design a better solution. Furthermore, the findings contribute to the development of a more equitable, human-centred digital future by understanding its impact on the healthcare sector. This research highlights the importance of providing quality digital interactions and ensuring that health technologies are designed and adapted to the needs of industry, therapists, and patients, paving the way for future integration of virtual reality in areas of rehabilitation such as telerehabilitation and the use of virtual therapists.

REFERENCES

[1] 2021. DJI Mic. https://www.dji.com/uk/photo

[2] 2023. Adobe Premiere Pro. https://www.adobe.com/uk/products/premiere.html

[3] Steven J. Ackerman and Mark J. Hilsenroth. 2003. A review of therapist characteristics and techniques positively impacting the therapeutic alliance. *Clinical Psychology Review* 23, 1 (Feb. 2003), 1–33. https://doi.org/10.1016/S0272-7358(02)00146-0

[4] William C Adams. 2015. Conducting semi-structured interviews. *Handbook of practical program evaluation* (2015), 492–505. Publisher: Wiley Online Library.

[5] Nicholas Aderinto, Gbolahan Olatunji, Muili Opeyemi Abdulbasit, Mariam Edun, Gbolahan Aboderin, and Emmanuel Egbunu. 2023. Exploring the efficacy of virtual reality-based rehabilitation in stroke: a narrative review of current evidence. *Annals of Medicine* 55, 2 (Dec. 2023), 2285907. https://doi.org/10.1080/07853890.2023.2285907 Publisher: Taylor & Francis _eprint: https://doi.org/10.1080/07853890.2023.2285907.

[6] Jared Aida, Brian Chau, and Justin Dunn. 2018. Immersive virtual reality in traumatic brain injury rehabilitation: A literature review. *NeuroRehabilitation* 42, 4 (Jan. 2018), 441–448. https://doi.org/10.3233/NRE-172361 Publisher: IOS Press.

[7] Michael V Angrosino. 2016. *Naturalistic observation*. Routledge.

[8] Rita B. Ardito and Daniela Rabellino. 2011. Therapeutic Alliance and Outcome of Psychotherapy: Historical Excursus, Measurements, and Prospects for Research. *Frontiers in Psychology* 2 (2011). https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2011.00270

[9] Folarin Babatunde, Joy MacDermid, and Norma MacIntyre. 2017. Characteristics of therapeutic alliance in musculoskeletal physiotherapy and occupational therapy practice: a scoping review of the literature. *BMC Health Services Research* 17, 1 (May 2017), 375. https://doi.org/10.1186/s12913-017-2311-3

[10] Silvia Bargeri, Sabrina Scalea, Federica Agosta, Giuseppe Banfi, Davide Corbetta, Massimo Filippi, Elisabetta Sarasso, Andrea Turolla, Greta Castellini, and Silvia Gianola. 2023. Effectiveness and safety of virtual reality rehabilitation after stroke: an overview of systematic reviews. *eClinicalMedicine* 64 (Oct. 2023). https://doi.org/10.1016/j.eclinm.2023.102220 Publisher: Elsevier.

[11] Margaret J Bickers. 1993. Does verbal encouragement work? The effect of verbal encouragement on a muscular endurance task. *Clinical Rehabilitation* 7, 3 (Aug. 1993), 196–200. https://doi.org/10.1177/026921559300700303 Publisher: SAGE Publications Ltd STM.

[12] Megan Bishop, Nicola Kayes, and Kathryn McPherson. 2021. Understanding the therapeutic alliance in stroke rehabilitation. *Disability and Rehabilitation* 43, 8 (2021), 1074–1083. https://doi.org/10.1080/09638288.2019.1651909 Publisher: Taylor & Francis _eprint: https://doi.org/10.1080/09638288.2019.1651909.

[13] Megan Bishop, Nicola M Kayes, and Kathryn M. McPherson. 2019. Understanding the therapeutic alliance in stroke rehabilitation. *Disability and Rehabilitation* 43, 8 (Aug. 2019), 1074–1083. https://doi.org/10.1080/09638288.2019.1651909 MAG ID: 2180140423.

[14] Edward S. Bordin. 1979. The generalizability of the psychoanalytic concept of the working alliance. *Psychotherapy* 16, 3 (Jan. 1979), 252–260. https://doi.org/10.1037/h0085885 MAG ID: 2044661514.

[15] Marilyn B. Cole and Valnere McLean. 2003. Therapeutic Relationships Re-Defined. *Occupational Therapy in Mental Health* 19, 2 (March 2003), 33–56. https://doi.org/10.1300/J004v19n02_03 Publisher: Taylor & Francis _eprint: https://doi.org/10.1300/J004v19n02_03.

[16] Stephanie Elena Crowe, Mamehgol Yousefi, Bahareh Shahri, Thammathip Piumsomboon, and Simon Hoermann. 2024. Interactions with virtual therapists during motor rehabilitation in immersive virtual environments: a systematic review. *Frontiers in Virtual Reality* 5 (2024). https://www.frontiersin.org/articles/10.3389/frvir.2024.1284696

[17] Adam O. Horvath. 2001. The Therapeutic Alliance: Concepts, Research and Training. *Australian Psychologist* 36, 2 (July 2001), 170–176. https://doi.org/10.1080/00050060108259650 MAG ID: 2001133629.

[18] Adam O. Horvath and B. Dianne Symonds. 1991. Relation between Working Alliance and Outcome in Psychotherapy: A Meta-Analysis. *Journal of Counseling Psychology* 38, 2 (April 1991), 139–149. https://doi.org/10.1037/0022-0167.38.2.139 MAG ID: 2088864483.

[19] Pamela A. Klonoff, David G. Lamb, and Steven W. Henderson. 2001. Outcomes from milieu-based neurorehabilitation at up to 11 years post-discharge. *Brain Injury* 15, 5 (2001), 413–428. https://doi.org/10.1080/02699050116744 Publisher: Taylor & Francis _eprint: https://doi.org/10.1080/02699050116744.

[20] Kate Laver, Stacey George, Susie Thomas, J. E. Deutsch, and Maria Crotty. 2015. Virtual reality for stroke rehabilitation: an abridged version of a Cochrane review. *European journal of physical and rehabilitation medicine* 51, 4 (2015), 497–506. ISBN: 1973-9087.

[21] Kate Laver, Fabian Lim, Karen Reynolds, Stacey George, Julie Ratcliffe, Sharon Sim, and Maria Crotty. 2012. Virtual Reality Grocery Shopping Simulator: Development and Usability in Neurological Rehabilitation. *Teleoperators and Virtual Environments - Presence* 21 (April 2012), 183–191. https://doi.org/10.1162/PRES_a_00098

[22] Kate E. Laver, Belinda Lange, Stacey George, Judith E. Deutsch, Gustavo Saposnik, and Maria Crotty. 2017. Virtual reality for stroke rehabilitation. *Cochrane Database of Systematic Reviews* 11 (2017). https://doi.org/10.1002/14651858.CD008349.pub4 Publisher: John Wiley & Sons, Ltd.

[23] Anthony H. Lequerica, Cathy S. Donnell, and Denise G. Tate. 2009. Patient engagement in rehabilitation therapy: physical and occupational therapist impressions. *Disability and Rehabilitation* 31, 9 (Jan. 2009), 753–760. https://doi.org/10.1080/09638280802309095 Publisher: Taylor & Francis _eprint: https://doi.org/10.1080/09638280802309095.

[24] Michael J. Lukacs, Shahan Salim, Michael J. Katchabaw, Euson Yeung, and David M. Walton. 2022. Virtual reality in physical rehabilitation: a narrative review and critical reflection. *Physical Therapy Reviews* 0, 0 (July 2022), 1–9. https://doi.org/10.1080/10833196.2022.2105077 Publisher: Taylor & Francis _eprint: https://www.tandfonline.com/doi/pdf/10.1080/10833196.2022.2105077.

[25] Maria Grazia Maggio, Rosaria De Luca, Francesco Molonia, Bruno Porcari, Massimo Destro, Carmela Casella, Ramona Salvati, Placido Bramanti, and Rocco Salvatore Calabro. 2019. Cognitive rehabilitation in patients with traumatic brain injury: A narrative review on the emerging use of virtual reality. *Journal of Clinical Neuroscience* 61 (March 2019), 1–4. https://doi.org/10.1016/j.jocn.2018.12.020

[26] Ruth Parry. 2005. A video analysis of how physiotherapists communicate with patients about errors of performance: insights for practice and policy. *Physiotherapy* (2005). https://doi.org/10.1016/j.physio.2005.05.004 MAG ID: 2065610641.

[27] Barbara Paterson and Shannon Scott-Findlay. 2002. Critical Issues in Interviewing People with Traumatic Brain Injury. *Qualitative Health Research* 12, 3 (March 2002), 399–409. https://doi.org/10.1177/104973202129119973 Publisher: SAGE Publications Inc.

[28] Paul ten Have. 1999. Doing Conversation Analysis: A Practical Guide. (1999). MAG ID: 1561057419.

[29] Casey L. Peiris, Nicholas F. Taylor, and Nora Shields. 2012. Patients value patient-therapist interactions more than the amount or content of therapy during in-patient rehabilitation: a qualitative study. *Journal of Physiotherapy* 58, 4 (Dec. 2012), 261–268. https://doi.org/10.1016/S1836-9553(12)70128-5

[30] Rafael Zambelli Pinto, Manuela L. Ferreira, Vinicius C. Oliveira, Marcia R. Franco, Roger Adams, Christopher G. Maher, and Paulo H. Ferreira. 2012. Patient-centred communication is associated with positive therapeutic alliance: a systematic review. *Journal of Physiotherapy* 58, 2 (June 2012), 77–87. https://doi.org/10.1016/S1836-9553(12)70087-5

[31] George P. Prigatano, Pamela S. Klonoff, Kevin P. O'Brien, Irwin M. Altman, Kiran Amin, Dennis Chiapello, Janet Shepherd, Marie Cunningham, and Maria Mora. 1994. Productivity after neuropsychologically oriented milieu rehabilitation. *The Journal of Head Trauma Rehabilitation* 9 (1994), 91–102. https://doi.org/10.1097/00001199-199403000-00011 Place: US Publisher: Lippincott Williams & Wilkins.

[32] Susan Ayres Rosa and Betty Risteen Hasselkus. 1996. Connecting with Patients: The Personal Experience of Professional Helping. *The Occupational Therapy Journal of Research* 16, 4 (Oct. 1996), 245–260. https://doi.org/10.1177/153944929601600402 Publisher: SAGE Publications.

[33] Jonathan Smith, Paul Flowers, and Michael Larkin. 2009. *Interpretative Phenomenological Analysis: Theory, Method and Research*. Vol. 6. Journal Abbreviation: Qualitative Research in Psychology Publication Title: Qualitative Research in Psychology.

[34] U. Talvitie and M. Reunanen. 2002. Interaction between Physiotherapists and Patients in Stroke Treatment. *Physiotherapy* (2002). https://doi.org/10.1016/s0031-9406(05)60931-5 MAG ID: 2040401300.

[35] Renee R. Taylor. 2020. *The Intentional Relationship: Occupational Therapy and Use of Self*. F.A. Davis. Google-Books-ID: DIzKDwAAQBAJ.

[36] Di Thomson. 2008. An ethnographic study of physiotherapists' perceptions of their interactions with patients on a chronic pain unit. *Physiotherapy Theory and Practice* 24, 6 (Nov. 2008), 408–422. https://doi.org/10.1080/09593980802511805 MAG ID: 2135432568.

[37] Kien T.P. Tran, Sungchul Jung, Simon Hoermann, and Robert W. Lindeman. 2019. MDI: A Multi-channel Dynamic Immersion Headset for Seamless Switching between Virtual and Real World Activities. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. 350–358. https://doi.org/10.1109/VR.2019.8798240 ISSN: 2642-5254.

[38] Paulette M. van Vliet and Gabriele Wulf. 2006. Extrinsic feedback for motor learning after stroke: What is the evidence? *Disability and Rehabilitation* 28, 13-14 (Jan. 2006), 831–840. https://doi.org/10.1080/09638280500534937 Publisher: Taylor & Francis _eprint: https://doi.org/10.1080/09638280500534937.

[39] Irene Walsh. 2007. Small Talk Is "Big Talk" in Clinical Discourse: Appreciating... : Topics in Language Disorders. *Topics in Language Disorders* 27, 1 (2007), 24–36. https://journals.lww.com/topicsinlanguagedisorders/abstract/2007/01000/small_talk_is__big_talk__in_clinical_discourse_.4.aspx

[40] Carolee J Winstein. 1991. Knowledge of Results and Motor Learning—Implications for Physical Therapy. *Physical Therapy* 71, 2 (Feb. 1991), 140–149. https://doi.org/10.1093/ptj/71.2.140

Received 2 May 2024; revised 16 May 2024; accepted X June 2024