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Human interactions remain at the heart of rehabilitation with advanced technology: a practice-embedded longitudinal qualitative study with allied health clinicians

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Abstract

Background Technology is gaining momentum in rehabilitation. While evidence is emerging, a growing number of rehabilitation facilities are implementing devices, though with variable success. A public-private rehabilitation provider in Australia recently opened a technology therapy centre with robotic and virtual reality devices. This study was embedded in the setting, which saw substantial clinician uptake of devices and presented a unique opportunity to explore clinician experiences, perceptions and factors influencing uptake, implementation and sustainment of advanced technology in practice.

Methods A longitudinal qualitative study was conducted, involving interviews with clinicians at three timepoints across the first 16 months of the centre opening. Allied health clinicians in the organisation ($n=119$) were invited to participate in interviews, which were audio-recorded, transcribed, coded and analysed using an inductive thematic approach.

Results In total, 63 interviews were conducted with 25 allied health clinicians across inpatient, outpatient and community rehabilitation services. An overarching finding that *human interactions remain at the heart of rehabilitation with advanced technology*, comprised three major themes with 12 subthemes. (1) *Technology integration involves cognitive and emotional labour for clinicians*, stemming from determining the value-add of advanced technology, juggling learning demands and negotiating patients' high expectations of technology. (2) *Contextual factors shape clinician uptake and ongoing use of technology*, including organisational culture, professional discipline, rehabilitation setting, patient characteristics and device features. (3) *Shared understanding and priorities promote technology implementation and sustainment*, including understanding advanced technology in relation to conventional therapy, creating a well-designed training model, equipping clinicians to manage patient expectations and maintaining a commitment to evidence-based practice.

Conclusions While further high-quality evidence regarding the effectiveness of technology in rehabilitation is required, clinicians in this study perceived advanced technology as an adjunct to conventional therapy, with benefits

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for enhancing therapy dosage, patient engagement, manual handling and providing objective feedback. Important practice-derived considerations for integrating advanced technologies in rehabilitation include: developing clinician technical, clinical reasoning and interpersonal skills, reducing contextual barriers and fostering a positive organisational culture with strong leadership and targeted initiatives to support clinicians. Successful implementation of advanced rehabilitation technologies relies on clinician buy-in to champion change within an enabling person-centered context.

Keywords Rehabilitation, Technology, Virtual reality, Robotics, Exoskeleton device, Digital health, Implementation science, Allied health personnel, Qualitative methods

Introduction

There is growing recognition that technology will play an important role in driving strategic growth in our healthcare systems [1]. The World Health Organization has described the digital transformation of healthcare as disruptive, yet beneficial for therapy, patient self-management, person-centered care, research and evidence-based knowledge and skills for healthcare professionals [1]. Rehabilitation is a vital component of healthcare where technological interventions are gaining momentum as novel therapy approaches [1–3]. Current evidence for rehabilitation technology is emerging, with some studies citing benefits for improving patient engagement in rehabilitation [4–6], increasing therapy dosage [7–9], reducing clinician manual handling [5, 10, 11] and earlier introduction of rehabilitation to patients [12, 13]. However, generally low-quality evidence and conflicting findings question the impact of technology on improving patient outcomes beyond conventional therapy methods [9, 14, 15]. Despite this, a growing number of rehabilitation facilities are incorporating technology into practice [16–18], although implementation success and clinician uptake remain highly variable [13, 16, 17, 19, 20]. Therefore, research in this field must examine implementation alongside effectiveness to maintain pace with rapid technological advancements.

Implementing technological interventions requires building workforce capacity, adapting organisational processes, and strengthening management systems [1, 10, 18, 19, 21]. However, there is a dearth of evidence to support adopting, implementing and sustaining technology use in rehabilitation [17, 21–26]. Current research often focuses on barriers and facilitators to technology uptake, overlooking interactions between factors which are fundamental in complex healthcare systems [21, 27]. Importantly, as key decision-makers, clinicians often serve as gatekeepers to implementing new healthcare interventions [13, 28, 29]. Therefore, clinician acceptance, clinical reasoning and confidence in using technology are crucial for successful integration into practice [18, 30, 31]. Without an in-depth understanding of clinician perspectives on the practicalities of integrating technology into real-world rehabilitation services, key implementation issues are likely to remain [20, 23, 32].

In 2022, a public-private rehabilitation provider in Australia opened a technology therapy centre with 25 advanced technologies, defined in this study as robotics, virtual reality, multi-channel functional electrical stimulation, sensor-based devices, or devices with a combination of these features [11, 33–35]. Within the first year, clinicians used advanced technologies 4,208 times with 269 patients [35]. Current studies typically focus on a limited number of technologies, single clinician disciplines, and specific patient populations at a single timepoint [12, 22, 25, 28, 36]. Therefore, the opening of the centre presents a unique opportunity to explore the factors which contributed to substantial clinician uptake of a wide range of advanced technologies across clinician disciplines, patient populations and rehabilitation settings. The research questions of this study were: (1) What are the experiences and perceptions of rehabilitation clinicians integrating new advanced technologies into practice? (2) Are experiences and uptake of advanced technologies different across rehabilitation settings? (3) What factors influence clinician uptake of advanced technologies? (4) What are rehabilitation clinicians' views on sustaining technology implementation?

Method

Study design

A longitudinal qualitative study was conducted using an inductive thematic approach [37–40]. Clinicians were invited to participate in semi-structured interviews at three timepoints across the first 16 months of the technology therapy centre opening (see Table 1).

The Consolidated Criteria for Reporting Qualitative Research was used to guide the reporting of this study [41]. Ethics approval was provided by Northern Sydney Local Health District (NSLHD) Human Research Ethics Committee on 19 May 2022 (2022/ETH00364).

Study setting

The study site is a combined public-private organisation in Australia which provides rehabilitation services primarily to adults with neurological conditions, with specialties in spinal cord and brain injury. Rehabilitation services include five outpatient/community services, three inpatient units and two community only services.

Table 1 Dates and primary focus of each interview timepoint

Timepoint	Date	Primary focus
T1	July to September 2022 (first 3 months of centre opening)	Expectations and perceptions of advanced technology
T2	January to March 2023 (7 to 9 months after opening)	Experiences of using advanced technology
T3	July to October 2023 (13 to 16 months after opening)	Aspects of implementation and sustainment of advanced technology in practice

The technology centre opened in July 2022 and was accessible to allied health clinicians ($n = 119$) across all services. Details regarding clinicians' usage of devices, including which devices were used, who used the devices (categorised by clinicians, patients and rehabilitation service), why devices were used and therapy dosage achieved through device use are published elsewhere [35].

Recruitment and sampling

All allied health clinicians (45 working in inpatient services, 67 in outpatient/community services and 7 across all settings) were invited to participate in semi-structured interviews. Sampling was purposive and aimed for representation of all allied health disciplines across inpatient, outpatient and community services. Recruitment emails were sent by Professional Leaders of each clinical discipline at T1 and T2, with up to two follow-up emails at each timepoint. Due to the longitudinal nature of the study, recruitment was ceased by the end of T2. Maximum variation sampling requirements were met, and concurrent analysis of the data indicated that data were sufficient to answer our research questions [42, 43].

Data collection

A semi-structured interview guide was developed and iteratively updated to incorporate learnings from previous timepoints (Additional File 1). The guide was used flexibly to encourage clinicians to elaborate on topics important to them. Individual interviews were conducted in-person in a private meeting room at the study site, or over Microsoft Teams, by JP or LP. All interviews were audio-recorded, professionally transcribed verbatim and checked by the respective interviewer. As LP works clinically at the study site, she only interviewed participants with whom she did not directly work and remained blinded to other participants. JP, who has no managerial relationship with any clinicians, interviewed all other participants, who each verbally consented to LP accessing their de-identified transcripts. Transcripts were not returned to participants for comment or correction.

Data analysis

Interview transcripts were independently coded in NVivo R1/2020 (QSR International, Melbourne, Australia) by LP and on paper by JP. Due to the novelty of advanced rehabilitation technology, the research team chose an inductive approach to develop data-driven themes, rather than being informed by pre-existing theory [37]. Codes evolved throughout analysis, with LP and JP meeting regularly to discuss codes [44]. Themes were collaboratively derived from the data by LP and JP, with particular attention paid to codes with high repetition across participants and contradicting codes, both within and across each timepoint (i.e. cross-sectional and temporal approaches [40]). The final codebook, including codes mapped to themes and subthemes alongside illustrative participant quotes are detailed in Additional File 2. LH and CS were consulted to discuss findings, additional interpretations of the data and to reach agreement on the final themes. Participant checking was also conducted to confirm credibility of our findings [45]. Participants were informed that this process was unlikely to change the results, but aimed to gather feedback and summarise this as part of the findings.

Researcher characteristics and reflexivity

This study was underpinned by a reflexive approach to maintain awareness of researcher influences on the research [46]. The research team included female researchers and clinicians, both internal and external to the study site. JP and LP were known to participants prior to the study, with LP working as an outpatient/community clinician and JP as the director of research. Guidance was followed to moderate the influence of insider researcher status on the qualitative process [37, 46–48]. LP and JP used field notes, memos and reflexive journals to support self-reflection. Collaboration between all members of the research team, particularly those external to the organisation was vital for reflexivity, validation and triangulation of interpretations [47]. Inviting participant feedback was also important to both affirm and challenge the study findings, maximising transparency and credibility [45].

Results

A total of 63 interviews were conducted, involving 25 clinicians, between July 2022 to October 2023. Sixteen clinicians were interviewed across three timepoints, six were interviewed at two timepoints and three were interviewed at one timepoint. Drop-outs occurred due to extended leave ($n = 2$) or resignations ($n = 2$). Interviews ranged from 19 to 83 min, with an average duration of 48 min. Participants included nine occupational therapists, eight physiotherapists, three recreational therapists, two speech pathologists, two allied health

assistants and one dietician. Participant demographics can be found in Table 2.

One overarching finding comprised of three major themes and 12 subthemes, each detailed below, with key de-identified quotes from participants in italics used to illustrate findings. Additional participant quotes can be found in Additional File 2. Figure 1 depicts a schematic representation of findings, while Table 3 provides an overview of themes and subthemes linked to research questions and data collection aims.

Table 2 Participant demographics across each timepoint

Demographic		T1 ($n=20$)	T2 ($n=22$)*	T3 ($n=21$)*
		n (%)	n (%)	n (%)
Clinical Setting	Community and outpatient	12 (60)	13 (59)	12 (57)
	Inpatient only	4 (20)	5 (23)	5 (24)
	Community only	1 (5)	1 (5)	1 (5)
	Outpatient only	1 (5)	1 (5)	1 (5)
	Community, inpatient, and outpatient	2 (10)	2 (9)	2 (10)
Age	20–29	9 (45)	12 (55)	11 (52)
	30–39	5 (25)	4 (18)	4 (19)
	40–49	4 (20)	4 (18)	4 (19)
	50–59	2 (10)	2 (9)	2 (10)
Gender	Male	5 (25)	5 (23)	5 (24)
	Female	15 (75)	17 (77)	16 (76)
Professional discipline	Occupational Therapy	8 (40)	8 (36)	8 (38)
	Physiotherapy	7 (35)	7 (32)	7 (33)
	Recreational Therapy	3 (15)	3 (14)	2 (10)
	Dietetics	1 (5)	0 (0)	0 (0)
	Speech Pathology	1 (5)	2 (9)	2 (10)
	Allied Health Assistant	0 (0)	2 (9)	2 (10)
Years since graduation	< 1 year	1 (5)	2 (9)	2 (10)
	1–5 years	4 (20)	6 (27)	6 (29)
	6–10 years	5 (25)	7 (32)	6 (29)
	11–20 years	6 (30)	4 (18)	4 (19)
	21–30 years	3 (15)	2 (9)	2 (10)
	> 30 years	1 (5)	1 (5)	1 (5)
Post-graduate qualifications	None	10 (50)	12 (55)	11 (52)
	Master's degree	5 (25)	5 (23)	5 (24)
	Other	4 (20)	5 (23)	5 (24)
	Doctorate	1 (5)	0 (0)	0 (0)
Years in rehabilitation	< 1 year	1 (5)	2 (9)	2 (10)
	1–5 years	6 (30)	8 (36)	8 (38)
	6–10 years	5 (25)	6 (27)	5 (24)
	11–20 years	5 (25)	4 (18)	4 (19)
	21–30 years	3 (15)	2 (9)	2 (10)
Years at study site	< 1 year	6 (30)	8 (36)	8 (38)
	1–5 years	4 (20)	6 (27)	6 (29)
	6–10 years	5 (25)	4 (18)	3 (14)
	11–20 years	4 (20)	3 (14)	3 (14)
	21–30 years	1 (5)	1 (5)	1 (5)
Currently using advanced technology	Yes	18 (90)	22 (100)	21 (100)
	No	2 (10)	0 (0)	0 (0)

Human interactions remain at the heart of rehabilitation with advanced technology

Repeated interviews with allied health clinicians across the first 16 months of the technology centre opening revealed that clinician uptake of technology did not happen by chance or by the devices simply being made available to clinicians. Rather, integrating advanced technology required substantial learning, practice change and targeted initiatives. Successful integration of advanced technology into rehabilitation relied on clinician buy-in to champion change in an enabling person-centered context that retains human interactions at the heart of rehabilitation.

Theme 1: Technology integration involves cognitive and emotional labour for clinicians

Incorporating advanced technology into rehabilitation demanded a significant investment of time and energy from clinicians, as reflected in the following three subthemes.

Determining the value-add and relevance of advanced technology

To undertake the cognitive and emotional labour associated with integrating advanced technology, clinicians had to first determine the value-add and relevance of technology for their practice. Many participants were enthusiastic about technology, excited to be at the forefront of rehabilitation advancement and growth. This enthusiasm was accompanied by a sense that technology offered personal benefits such as professional development, mental stimulation, increased creativity and enhanced clinical reasoning.

Yet, positivity towards technology was not universal. Some participants noted the time and energy required to learn how to use advanced technology was disproportionate to the small role it played in their practice: *"How can I…contribute all of this time and effort into training…when there's so many other things. I guess that comes back to, it's not impactful on my day-to-day because it's a smaller portion of my day"*. Others were concerned about narrowing their skillset to a niche area of rehabilitation,

Table 2 (continued)

Number of devices used	0	2 (10)	2 (9)	0 (0)
	1–2	6 (30)	2 (9)	2 (10)
	3–5	4 (20)	4 (18)	3 (14)
	6–10	7 (35)	10 (45)	13 (62)
	11–20	1 (5)	4 (18)	3 (14)

NB: Percentages may not add up to 100% due to rounding

*T2: 17 clinicians returned from T1, 3 clinicians dropped out and 5 new clinicians were recruited

T3: 21 clinicians returned from T2 (of whom 16 were also in T1) and 1 clinician dropped out

potentially losing other important skills, such as conventional manual handling.

Juggling overwhelming learning and emotional demands

Regardless of their attitudes towards technology, all interviewees articulated the struggle to prioritise learning and using technology in a time-poor clinical environment. Beyond the constraints of time, this involved overwhelming cognitive labour for clinicians while keeping up with numerous demands in busy clinical settings. Participants also described navigating a myriad of complex patient emotions in rehabilitation, arising from expectations of recovery, adjustment to illness and supporting transitions into the community. Managing these emotions alone was at times overwhelming and took an emotional toll on clinicians: *"At the end of a day [clinicians] can be absolutely shattered, energy, emotionally and physically."*

Many participants also grappled with feeling daunted in the early phase of technology uptake. Clinicians felt responsible for delivering effective therapy and did not want to appear incompetent to patients. Applying new knowledge while still developing competence made some *"feel like a fraud"*, and going from having confidence in their clinical skills to feeling like a novice again left many participants feeling vulnerable.

Given the labour of integrating advanced technology, most participants perceived patient satisfaction with advanced technology to be higher than theirs. To choose to invest their precious time and energy into advanced technology, some were bolstered by open-mindedness and a love of learning, while others were motivated by successful experiences of using technology with patients.

Negotiating pressures from patients' high expectations of advanced technology

A major aspect of the emotional labour many clinicians undertook was a direct result of patients' high expectations of advanced technology. Clinicians in this study described patients as being overwhelmingly positive and excited about technology, particularly robotic devices. This excitement triggered false hopes and unrealistic expectations in many patients, felt to be driven by individuals seeking a *"cure"*. The messaging promoting advanced technology in media and marketing campaigns was also felt to exacerbate patients' high expectations. In the early stages of integrating technology, although participants described the importance of minimising false hopes, understanding of how to effectively manage patients' expectations of technology was limited. This added an additional layer of responsibility on clinicians.

> *"Some clients think tech is the magic that's going to make everything perfect for them. For some people it will work really beautifully, but for some clients it [won't]. I've really had to work on my ability to set realistic expectations around it."*

Recognising the human elements of clinicians and their own emotional needs was crucial for integrating advanced technology into practice. Despite the cognitive and emotional labour, many clinicians in this study bought into technology as part of the future of rehabilitation and were willing to take on the extra work, acknowledging the need to embrace technology to *"evolve and move with the times"*.

Theme 2: Contextual factors shape clinician uptake and ongoing use of technology

An interplay of contextual factors influenced clinician access to, perceived need for, and uptake of advanced technology. The following five subthemes detail these factors.

Organisational culture and initiatives impact clinician engagement with technology

Organisational factors were pivotal in influencing clinician engagement, uptake and attitudes towards advanced technology. A key organisational initiative was appointing an advanced technology lead to facilitate training, guide implementation, answer clinical questions and assist with technological troubleshooting. *"[The lead is] such a good resource. You need someone…in that role"*. Clinicians also highly valued learning from, collaborating with and supporting each other. As such, a positive workplace culture of respect and support was a powerful facilitator for many interviewees, including an enabling dynamic of being equally willing to ask for and provide help: *"Everybody's really approachable and keen to learn and keen to help and so that really breaks down barriers"*.

Leadership also played a significant role in shaping workplace culture and facilitating technology engagement. Amid the ongoing practice change required for technology uptake, managerial support and recognition were key for maintaining team morale. Practical supports included providing clinical backfill, allowing time to learn technology, and reducing pressures to meet quotas for clinical care while learning. Other initiatives included

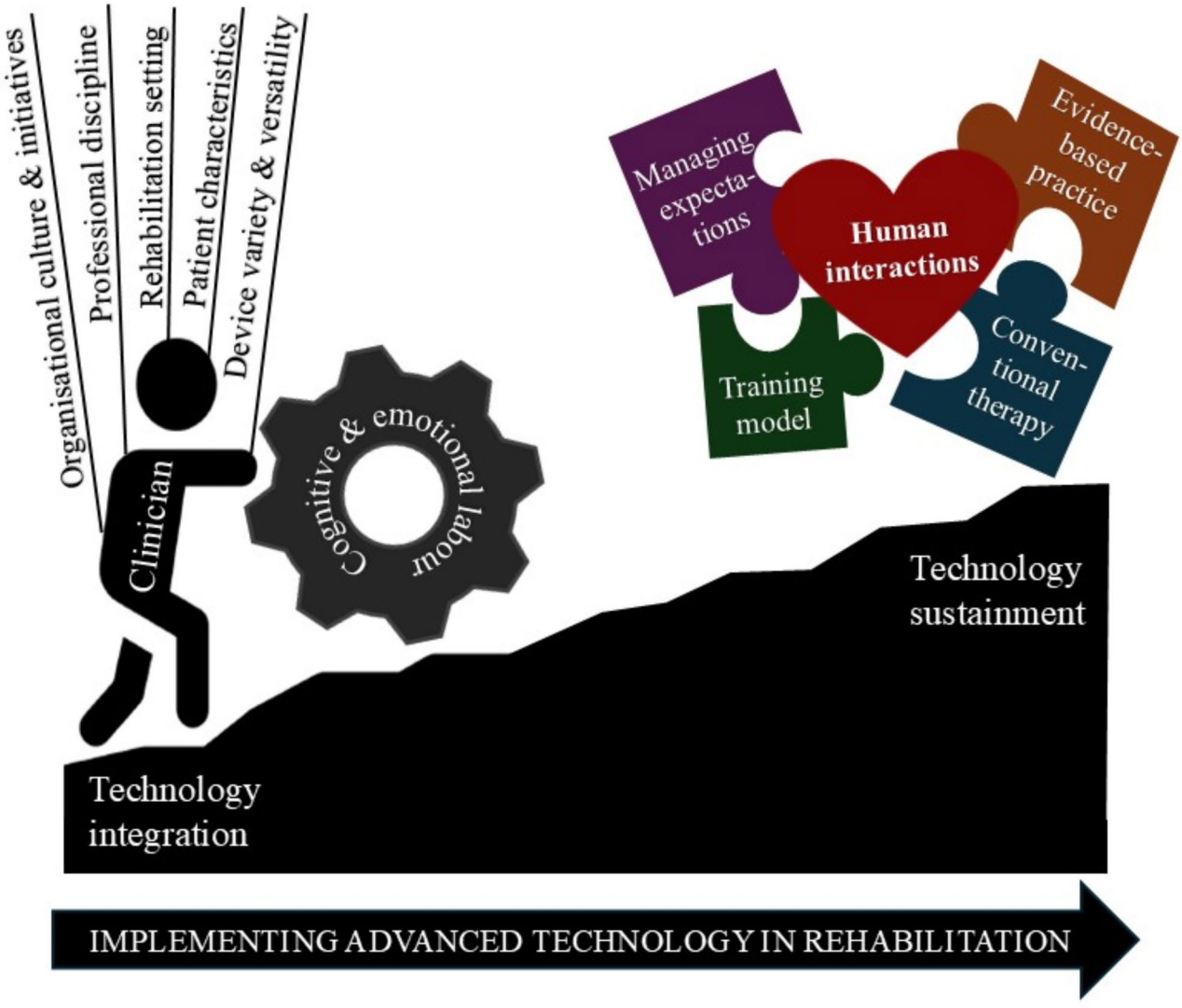

Fig. 1 Schematic representing study findings of clinician experiences of integrating advanced technology into rehabilitation practice

employing allied health assistants to assist with set-up, use and cleaning of devices. Meanwhile, inefficient processes, such as requiring bookings to access devices were seen as barriers.

Clinicians' professional discipline influences their relationship with technology

Interviewees from different professional disciplines exhibited distinct differences in their therapeutic approaches and uptake of advanced technology. A common observation was that the advanced technologies were predominantly *"impairment focused".* Consequently, incorporating technology into therapy required additional considerations for disciplines, such as occupational and recreational therapists, who typically work towards participation-level goals within real-world contexts (e.g., return to work or sport). In contrast, physiotherapists, who routinely address impairments (e.g., muscle weakness) and activity limitations (e.g., difficulty walking), found it easier to incorporate advanced technology into their practice.

The make-up of a clinician's role also influenced their capacity for practice change. For example, occupational therapists are commonly involved in environmental modification and equipment prescription. Meanwhile, recreational therapists often address activity modification, equipment and support needs, which involve substantial learning given the diverse recreational interests of patients. The more tasks outside impairment-based therapy and task-practice occupied a clinician's role, the less capacity they had to learn and use advanced technology.

Table 3 Overview of themes and subthemes linked to research questions and data collection aims

Overarching finding: Human interactions remain at the heart of rehabilitation with advanced technology			
Theme	**Subthemes**	**Related research question(s)**	**Related data collection aim**
Technology integration involves cognitive and emotional labour for clinicians	Determining the value-add and relevance of advanced technology Juggling overwhelming learning and emotional demands Negotiating pressures from patients' high expectations of advanced technology	(1) What are the experiences and perceptions of rehabilitation clinicians integrating new advanced technologies into practice?	Expectations and perceptions of advanced technology (T1)
Contextual factors shape clinician uptake and ongoing use of technology	Organisational culture and initiatives impact clinician engagement with technology Clinicians' professional discipline influences their relationship with technology Rehabilitation setting influences clinician access to and need for technology Patient characteristics influence clinician ability to utilise technology Device variety and versatility influence technology usability	(2) Are experiences and uptake of advanced technologies different across rehabilitation settings? (3) What factors influence clinician uptake of advanced technologies?	Experiences of using advanced technology (T2)
Shared understanding and priorities promote technology implementation and sustainment	Understanding the role of advanced technology in relation to conventional therapy A well-designed training model to develop clinician competence and confidence Equipping clinicians to delicately manage patient expectations Ongoing commitment to evidence-based practice to resolve uncertainties	(4) What are rehabilitation clinicians' views on sustaining technology implementation?	Aspects of implementation and sustainment of advanced technology in practice (T3)

Rehabilitation setting influences clinician access to and need for technology

There were substantial differences in technology uptake between inpatient, outpatient and community services. The convenience of patients coming directly to the therapist was a significant facilitator for outpatient services co-located in the technology centre. Meanwhile, logistical barriers, such as device booking, getting to and transporting the device, were particularly noteworthy for clinicians in community-based services. Scheduling sessions with advanced technology in inpatient settings was also challenging due to the reduced control clinicians had over their day. Inpatient clinicians required flexibility with their therapy sessions, which was challenging when sharing technology with services requiring regimented scheduling such as in outpatient or community settings.

Study participants also reported inpatient clinicians face many competing high priorities. These included patient discharges, admissions, writing funding reports, conducting group classes, addressing home modifications, equipment prescription, and patient safety on the ward. Longer admission periods, slower turnover of patients and the generally static nature of specialist inpatient rehabilitation caseloads also resulted in less opportunities for inpatient clinicians to build and maintain confidence in using devices. Finally, in inpatient settings, therapy objectives and pressures were often shaped by patient adjustment and facilitating safe discharges. In community settings, "*goals are around resettling at home and transitioning to a reduction in care*". Meanwhile, rehabilitation in the outpatient setting was primarily focused on providing impairment- and activity-related therapy. Therefore, in this study, advanced technology was easier to fit into an outpatient service model.

Patient characteristics influence clinician ability to utilise technology

Participants found their use of technology fluctuated depending on the presence of appropriate patients in their case-mix. Cognitive impairment was the most reported patient-related barrier to technology use. Participants found it challenging to introduce advanced technologies and explain the functional relevance to patients with cognitive impairment. Conventional therapy methods were described as more conducive for cognitively impaired patients due to familiarity and availability of contextual cues. Physical impairments in patients, such as contractures and spasticity also limited clinician use of advanced technology. One participant reported the advanced technologies currently available were often only suitable for addressing one impairment, "*for people who have issues in isolation… [not a] combination of issues*", making it challenging to accommodate the needs of patients with multiple complex impairments.

Time since injury was another important factor influencing clinician use of advanced technology, with participants expressing a preference for use with patients in the acute or sub-acute phase due to *"active rehab goals"* from being "*right in the middle of that neuroplasticity and relearning*". In contrast, achieving functional gains was reportedly harder for patients in the chronic phase of their condition, where improvements were often

incremental and impairment-focused. Advanced technology was also thought to be most helpful for patients who were motivated in their therapy as they were more ready to carryover feedback and learned skills into conventional therapy and daily life. Many interviewees noted the importance of patient adherence to independent therapy outside of therapy sessions: *"You can't just come here, the robot's not going to "fix" you…you "fix" yourself by doing the work".*

Device variety and versatility influence technology usability

Having a wide range of devices available was largely positive, as it offered variety in therapy and increased the likelihood of finding a device suitable for a patient's needs. However, having many devices increased the demand on training resources and contributed to challenges in clinician selection of a device to use. Clinicians in this study preferred devices which were easy to set-up, easy to use, not prescriptive and versatile in tailoring to a range of patients and activities. Conversely, technologies which did not replicate the demands of activities of daily living and had restricted movements or a *"fiddly set-up"* were less appealing.

The increasingly nuanced understanding of the contextual factors across timepoints revealed their dynamic interplay. Clinicians' experiences and uptake of technology were not only shaped by distinct factors, such as discipline or patient characteristics, but also by how factors intersected across settings and types of devices. This illuminated the need for direct communication channels between clinicians and leaders in the organisation to effectively address contextual barriers. Such interactions ensure clinicians can provide feedback and *"[stay] in the loop"*, while leaders can ensure *"the integration of feedback from below"*.

Theme 3: Shared understanding and priorities promote technology implementation and sustainment

Clinicians' understanding of implementing advanced technology became more sophisticated over time. Some participants, especially occupational therapists found themselves learning how to *"relate technology to function".* Others found increased confidence and experimentation with advanced technology was accompanied by less apprehension. By the third timepoint, many clinicians spoke more confidently about using the devices, as technology use became part of their everyday language. However, evidence of the additional load on clinicians and the five contextual factors remained, with some feeling fatigued from the intense focus on technology and referring to advanced technology as *"one part of many things that we do, and every bit is as important as the other"*. Ultimately, clinicians' focus remained on their patients and interactions with patients. Four subthemes related to clinicians' priorities during technology implementation and sustainment are described below.

Understanding the role of advanced technology in relation to conventional therapy

Participants in this study consistently positioned technology as a tool in the rehabilitation clinician's toolbox. Almost all participants reported the main benefit of using advanced technologies as increasing therapy dosage through its ability to enhance patient engagement in rehabilitation: *"[Technology] allows people to achieve the big amount of repetitions that are needed…[it can] make rehab a little less scary, a bit more fun"*. Advanced technology can also reduce the manual handling load on clinicians, collect objective measures and provide precise *"real-time feedback".* Due to the additional support provided by some devices, participants felt using advanced technology increased safety in therapy and allowed clinicians to do more therapy and challenge patients earlier in their rehabilitation journey.

However, advanced technologies were not considered endpoints of therapy in themselves. Conventional therapy was viewed as essential for translating impairment and activity-level gains into real-world benefits. Therefore, participants emphasised that advanced technology should not be positioned as better than, but complimentary to conventional methods.

A well-designed training model to develop clinician competence and confidence

Developing and maintaining clinician competence and confidence with technology was core to implementing and sustaining advanced technology use in practice. Participants want to *"feel confident to use [technology]…know what types of patients [to] use it for…what indications or contra indications there might be…how to adapt it to the patient…and if issues come up…[to] know how to trouble shoot it".* Developing confidence appeared to occur in two stages. Learning the practical device set-up and operation was followed by learning intricacies and using the device for a range of purposes with in-depth clinical reasoning.

Practical and hands-on initial training with a device was most useful, with guidance for device set-up and supervised sessions with patients. Participants also desired ongoing training in a variety of formats, including internal, external, one-to-one and small groups. Immersive learning in blocks of protected time or days was preferred by participants, opposed to intermittent sessions which posed challenges for consolidating learning. Train-the-trainer models, where trained clinicians were responsible for training untrained clinicians, were particularly challenging due to difficulties with coordinating clinicians' busy schedules. It was also important

for the organisation to create opportunities for clinicians to *"peer problem-solve"* issues without judgement or the expectation to master all aspects of technology.

Equipping clinicians to delicately manage patient expectations

Equipping clinicians to navigate delicate conversations was also fundamental for implementing and sustaining advanced technology use in rehabilitation: *"We need to skill up the staff in everything. Not just in using the tech, but other aspects that come around that."* Such conversations are not new in rehabilitation, with clinicians often discussing negative prognosis, patients *"plateauing"*, and managing general expectations *"around rehab…and what rehab means"*. However, advanced technology added a layer of complexity to these conversations.

Underpinning this was distinguishing between hope and false expectation and learning to establish realistic expectations without quashing hope. Clinicians in this study found that delicate conversations were best approached with transparency, clear communication and compassion. Raising these conversations with patients at the beginning of therapy and throughout was crucial, including setting realistic goals directly linked to activities of daily living to ensure the functional goal, not the technology, was the focus. Once patients achieved their goals or if they plateaued, it was seen as important to wean off advanced technology, try a different therapy approach or focus on patient self-management. Within outpatient services, one approach to managing patient expectations described by many participants was to offer time-limited blocks of therapy. Timeframes prompted clinicians and patients to revisit delicate conversations and retain realistic goals as the focus of therapy. To aid in managing patient expectations and alleviating pressure on clinicians, several also suggested that media and marketing should avoid *"promoting and showcasing [technology] for social media"*, but rather, highlight *"real patient outcomes and for real people"*.

Ongoing commitment to evidence-based practice to resolve uncertainties

Clinicians' sustained use of advanced technology remained fragile due to many ongoing uncertainties regarding evidence about device effectiveness, prescription and selection. The need for better clinical reasoning and evidence-based guidelines for device selection was highlighted by many participants: *"[We need] clearer clinical pathways for selection of devices…It would be good to see the research coming out…about what works, and why…to help with the development of clinical reasoning."*

In the absence of high-quality evidence, using outcome measures to inform appropriateness of technology use was considered crucial to justify therapy decisions and ensure evidence-based practice. Participants believed more rigorous evidence to support advanced technology use in rehabilitation should be prioritised, particularly regarding effectiveness for improving patient outcomes. There was a clear commitment amongst clinicians to align their practices to research evidence. However, the limited availability of robust evidence added to the fragility of implementing and sustaining advanced technology use in practice.

Participant checking

Prior to finalising the results and themes, 19 participants were invited via email to provide feedback on the study results. The other six participants were not able to be contacted due to resignations. Of the 19 participants, five provided feedback (26%). Feedback was positive, with participants reporting that the findings captured their experiences, the complexity of integrating technology into practice and reflected ongoing discussions across the organisation. One clinician reported that the findings *"validate [their] own experience…and gave great insight into the wider experiences of team members"*. No participants expressed disagreement with the findings, however one participant reported that the high expectations from patients was not their experience, as in their discipline the *"high tech equipment"* was less relevant. Finally, one clinician reported expecting more discussion regarding the value of the advanced technology lead, as this was *"absolutely critical to successful implementation"*.

Discussion

This longitudinal qualitative study explored clinicians' experiences, perceptions and factors influencing the integration of new advanced technologies in a real-world rehabilitation setting. A total of 63 interviews with 25 multidisciplinary clinicians were conducted. Findings provide valuable practical insights into uptake, implementation and sustainment of technology in rehabilitation. The multifaceted nature of integrating advanced technology into practice necessitates targeted initiatives to support clinicians and address context-specific factors. Successful implementation requires aligned priorities across the organisation, including a positive culture with strong leadership, commitment to evidence-based practice and development of clinicians' technical, clinical reasoning and interpersonal skills. Ultimately, embracing the human elements of rehabilitation and remaining person-centered are key.

High workloads and a lack of time are widely reported barriers to practice change for clinicians [49–52]. Novel findings from this study highlight that these challenges extend to the cognitive and emotional load on clinicians in clinical practice. Strategies to alleviate this load should be considered when implementing technology. In this

study, having a technology lead was crucial for guiding implementation, facilitating training, supporting clinical sessions and troubleshooting technology. Facilitating clinician collaboration was also important, as clinicians value learning from each other, likely due to the time-saving nature of receiving filtered and context-specific information. These strategies, combined with managerial support—such as allocating time for clinician training and providing clinical backfill where possible—also helped to address the barrier of limited time. There is also a need for a cohesive approach to technology integration at both an organisational and clinician level. To this end, a useful concept to consider is $R = MC^2$ (organisational *readiness* = the organisation's *motivation* to adopt an intervention x the organisation's *general capacity*, culture, or climate x *innovation-specific capacity*) [53]. In the context of advanced rehabilitation technology, findings from our study suggest that organisational readiness includes individual and collective clinician attitudes towards technology (*motivation*), clinician knowledge and capabilities regarding technology (*innovation-specific capacity)* and organisational culture, leadership and initiatives, such as comprehensive training models and processes to access technology (*general capacity).*

A key component of the cognitive and emotional labour faced by clinicians was the pressure to manage patients' high expectations of advanced technology. Previous literature in the field has emphasised developing clinicians' technical knowledge and clinical reasoning when implementing technology [13, 23, 32, 54]. A third element of training identified by our study, is the need to develop clinicians' interpersonal skills to navigate delicate conversations and set realistic expectations with patients. Previous studies have described a similar concept, the 'therapeutic alliance' between patients and therapists, as an active component of achieving better rehabilitation outcomes [55–57]. It is vital to consider how technology impacts the clinician-patient relationship, which influences patient outcomes, as well as clinician identity, job satisfaction and motivation [10, 25, 36]. Crucially, as identified by clinicians throughout our study, there is a need for robust evidence of the effectiveness and benefits of advanced technology. This is foundational for improving patient outcomes, generating sufficient clinician buy-in, informing staff training models and guiding future evidence-based practice. Future research should also clearly evaluate and define the patient population and rehabilitation setting(s) for which devices are effective. Such evidence would offer a better understanding of what using advanced technology can achieve and facilitate realistic expectations among patients, clinicians and rehabilitation organisations.

Findings in our study corroborate and extend findings from other studies within the field. Other qualitative studies conducted with various stakeholders across public and private rehabilitation settings in Australia, Asia, Europe and North America have found that clinician uptake of low-cost (e.g., smartphone applications, gaming consoles and telehealth) and high-cost (e.g., lower limb and upper limb robotics, virtual reality and sensor-based devices) technologies is influenced by technology-related, clinical, human behavioural, organisational and implementation process factors [10, 20, 22, 23, 25, 36]. A systematic review of 63 studies investigating determinants of robotic gait device implementation in rehabilitation found that determinants related to the inner setting, outer setting and implementation process are not well documented in the literature [24]. This demonstrates the importance of our findings which extensively discuss the inner setting through detailing contextual factors, including novel findings regarding variations across rehabilitation settings. Our study also highlights key processes and priorities for implementing and sustaining advanced technology in rehabilitation. Evaluating implementation strategies and developing implementation guidelines for technology across both public and private rehabilitation settings are important areas for future research. Finally, the longitudinal nature of our study allowed us to capture early and evolving clinician experiences with advanced technology, which increased the breadth and depth of our findings. Important study findings include clear practice-derived strategies with potential to directly impact clinical practice. Examples of this include important elements of a comprehensive staff training model and practical organisational initiatives to support clinicians, such as appointing a technology lead, fostering collaboration between clinicians, providing support personnel (such as allied health assistants) and ensuring managerial recognition of clinicians' efforts.

To our knowledge, this is the first longitudinal qualitative study in a real-world rehabilitation setting which saw substantial clinician uptake of multiple advanced technologies. A large number of interviews ($n = 63$) were conducted with multidisciplinary clinicians working with various patient populations across inpatient, outpatient and community rehabilitation. However, this study has some limitations. Firstly, this study was conducted at a single site, which was well-resourced and in a high-income country where funding models exist for patients to access long-term rehabilitation services. Costs related to technology purchase and maintenance did not feature as a main barrier in this study, which differs from other studies [22, 24]. This is important to investigate in future research. However, similarities between our findings and current evidence across a range of settings and countries, suggest that our findings are informative for other rehabilitation services. Secondly, insider research status can have both positive and negative influences on

the research [47]. Established rapport between interviewer and participant can lead to increased openness from common ground evident in this study through participants' candor in sharing both positive and negative perspectives of technology. Conversely, interviewers JP and LP's roles and own perspectives of technology have undeniable influences on discussions with participants and interpretation of the findings. As described in the methods above, this was managed through a reflexive approach and triangulation of interpretations. Thirdly, we acknowledge that "advanced technology" is a broad term with different meanings. In this study, the term aligns with the study site's definition, referring to robotics, virtual reality, multi-channel electrical stimulation and sensor-based devices. Other devices that may be considered "advanced technology" are not included in this study. Finally, this study did not include patient perspectives as patient interviews are planned as a separate study. Given the finding of intertwined needs between patients and clinicians, it is important to investigate patient experiences, perceptions and uptake of advanced technologies in rehabilitation.

Conclusions

This large, longitudinal qualitative study captured rehabilitation clinicians' experiences and perceptions of using advanced technology in practice and provides important insights regarding the integration of advanced technologies in rehabilitation. Our study involved clinicians from diverse allied health disciplines, a wide variety of advanced technologies, and was conducted across different rehabilitation settings. Findings provide practical considerations regarding the implementation and sustainment of advanced technology in rehabilitation. These include targeted initiatives to support clinicians undergoing practice changes, strategies to address contextual barriers, key elements of staff training, approaches for managing patient expectations and directions for future research. Amidst the demands of integrating new technologies, successful implementation relies on clinicians championing change in an enabling person-centered context with the ultimate shared vision of improving rehabilitation services and outcomes for patients.

Abbreviations

T1 Timepoint 1
T2 Timepoint 2
T3 Timepoint 3

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

All authors (LP, LH, CS, JP) were involved in the conception, design and data interpretation of this study. LP and JP conducted data acquisition and led the analysis. LP, JP and LH drafted the manuscript with input from CS for intellectual content. All authors have approved the final manuscript and agree to be accountable for the accuracy and integrity of the work.

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Data availability

The datasets (i.e., interview transcripts) generated during the study are not publicly available due to privacy and confidentiality reasons, however coding trees are available from the corresponding author upon reasonable request and with approval from the ethics committee and study site.

Declarations

Ethics approval and consent to participate

Ethics approval was provided by Northern Sydney Local Health District Human Research Ethics Committee on 19 May 2022 (2022/ETH00364).

Consent for publication

Not applicable.

Competing interests

Two members of the authorship team (LP and JP) are employed by the study site organisation. However, this research was undertaken independently from the organisation, as a part of LP's PhD at The University of Sydney.

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