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Original Article

Beyond the Initial Appeal: A Qualitative Study of Sustained Engagement with Virtual Reality and Wearable-Supported Rehabilitation After Stroke

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ABSTRACT

Background: Multimorbidity is often managed through disease-specific services, requiring patients to coordinate information, Background: Artificial intelligence (AI) is increasingly being incorporated into diagnostic, prognostic, and treatment-support processes in oncology, raising concerns regarding patient autonomy, trust, informed consent, explainability, and professional accountability. Objective: To explore how adults with current or previous oncology-care experience perceived autonomy, trust, informed consent, explainability, and clinician responsibility when considering hypothetical scenarios in which AI contributed to cancer-related diagnosis, prognosis, or treatment recommendations. Methods: A qualitative interpretive design was used. Fourteen adults with oncology-care experience were purposively recruited to provide variation in cancer experience and familiarity with digital health. Semi-structured interviews incorporated hypothetical scenarios involving AI-supported image analysis, individualized recurrence estimation, treatment recommendations, clinician–algorithm disagreement, and AI use without prior discussion. Data were analysed using reflexive thematic analysis. Results: Five interconnected themes were identified: conditional trust rather than technological trust; consent as an ongoing conversation; human accountability as the boundary of acceptable automation; explainability as practical meaning; and algorithmic pressure on autonomy. Participants generally perceived AI as acceptable when it augmented rather than replaced clinical reasoning, clinicians remained responsible for interpreting its outputs, and patients retained opportunities to question recommendations and consider alternatives. Participants also anticipated that AI-labelled recommendations could appear unusually objective and therefore become more difficult to reject, particularly when uncertainty and alternative options were not clearly communicated. Conclusion: Participants perceived AI-supported oncology decision-making as most compatible with autonomy when AI remained subordinate to accountable clinical judgment, disclosure was proportionate to its influence on the decision, explanations were clinically meaningful, and patients retained genuine opportunities to question or refuse recommendations. Because the study examined hypothetical scenarios rather than observed AI-supported consultations, the findings represent anticipated perceptions rather than demonstrated effects on clinical behaviour or autonomy. Keywords: artificial intelligence; oncology; patient autonomy; trust; informed consent; shared decision-making; qualitative research

EDITORIAL INFORMATION

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INTRODUCTION

Stroke remains a major cause of long-term adult disability and generates substantial and often prolonged rehabilitation needs across hospital, community, and home settings (1). Contemporary stroke rehabilitation emphasizes intensive, repetitive, task-specific, progressive, and personally meaningful practice, while recognizing that recovery is influenced by individual capacity, environmental circumstances, and the organization of rehabilitation services (2,3). These principles have increased interest in digital rehabilitation technologies that may extend opportunities for practice beyond conventional face-to-face therapy and provide structured feedback on performance and activity.

Virtual reality (VR) has emerged as one approach for increasing the intensity and interactivity of post-stroke rehabilitation. Systematic reviews and meta-reviews suggest that VR can improve selected motor outcomes, particularly when incorporated as an adjunct to conventional rehabilitation rather than as a

complete replacement for therapist-directed care (4,5). Evidence relating specifically to immersive VR similarly indicates potential benefits for upper-extremity and broader post-stroke rehabilitation outcomes, although substantial heterogeneity remains in device characteristics, therapeutic content, degree of immersion, treatment dose, and comparator interventions (6,7). Consequently, the effectiveness and acceptability of one VR system cannot necessarily be generalized to all digitally mediated rehabilitation environments.

Wearable technologies provide a complementary approach by extending measurement and feedback into everyday environments. Wearable sensors and commercially available activity-monitoring devices have been used to assess gait, mobility, upper-limb activity, physical activity, and home-based rehabilitation after stroke (8–10). Emerging trial evidence also suggests that wearable-supported interventions may contribute to upper- and lower-limb rehabilitation outcomes when integrated into structured rehabilitation programs (11). Nevertheless, feasibility studies indicate that the ability to collect movement data does not by itself guarantee sustained device use or meaningful incorporation of those data into rehabilitation behavior (12). Comfort, usability, device management, interpretation of feedback, and the relationship between measured activity and personally relevant functional goals therefore remain important considerations.

The longer-term value of digital rehabilitation depends not only on efficacy but also on whether people continue to perceive the technology as useful after initial novelty has diminished. Qualitative studies of VR after stroke have identified enjoyment, immediate feedback, challenge, and increased opportunities for practice as potential facilitators, while technical difficulty, fatigue, frustration, discomfort, monotony, and insufficient personalization may reduce engagement (13–17). Research on home-based stroke telerehabilitation similarly indicates that acceptance is shaped by perceived usefulness, confidence, available support, and compatibility with everyday routines rather than by access to technology alone (18). These considerations are particularly important after discharge, when adherence to rehabilitation activity may already be affected by fatigue, competing responsibilities, uncertainty regarding benefit, reduced confidence, and limited follow-up (19).

Sustained engagement should therefore not be reduced to whether a person initially likes a device or complies with a prescribed number of sessions. Continued use may instead reflect repeated judgements about whether the perceived rehabilitation value of a technology justifies its physical, cognitive, technical, and organizational demands. This issue may become more complex when VR and wearable technologies are used together. VR may structure therapeutic practice, while wearables can provide information about movement during or outside formal rehabilitation; however, the combined use of these technologies may also increase setup requirements, device-management demands, data burden, and the need for clinical interpretation. Despite growing evidence concerning the effectiveness and acceptability of individual digital rehabilitation technologies, less is known about how stroke survivors interpret continued use of combined VR- and wearable-supported rehabilitation after the initial period of enthusiasm has passed.

The present qualitative study therefore aimed to explore how adults living with stroke perceived sustained engagement with VR- and wearable-supported rehabilitation and to identify the circumstances that facilitated continued integration of these technologies into rehabilitation or contributed to reduced use and disengagement.

MATERIALS AND METHODS

Study Design and Methodological Orientation

A qualitative descriptive design was used to examine how adults living with stroke experienced and interpreted sustained engagement with VR- and wearable-supported rehabilitation. A qualitative approach was selected because the study sought to understand perceived value, burden, autonomy, feedback, and support in the context of continued technology use rather than to estimate a treatment effect. Reporting was informed by established qualitative research reporting principles, including the Consolidated Criteria for Reporting Qualitative Research and the Standards for Reporting Qualitative Research (20,21).

The analysis used reflexive thematic analysis, which was appropriate for identifying patterned meanings across participant accounts while retaining attention to variation, contradiction, and contextual interpretation (22). The analytic orientation was practical and person-centred, with particular attention to how participants understood the relationship between technology use, functional goals, physical capacity, rehabilitation demands, and available human support.

Participants and Sampling

The study included 14 adults aged 45–76 years who were between 3 and 24 months post-stroke and had experience using both VR-based exercise and a wearable device for rehabilitation-related monitoring or feedback. Participants were eligible when they had sufficient communication ability to discuss their rehabilitation experiences and had at least four weeks of experience with digitally supported rehabilitation.

Maximum-variation purposive sampling was used to capture diversity in age, sex, time since stroke, primary rehabilitation focus, home circumstances, and prior confidence with digital technology. The sample included participants whose rehabilitation primarily concerned upper-limb function, gait and balance, or mixed functional limitations. Sample adequacy was approached using the principle of information power, with emphasis on obtaining sufficiently detailed and varied accounts relevant to the focused research question rather than achieving statistical representation.

Data Collection

Data were generated using a semi-structured interview framework focused on participants' experiences of continued digital rehabilitation. The interview topics addressed initial expectations regarding VR and wearable technologies; changes in motivation over time; physical comfort and fatigue; practical management of devices; interpretation of performance and activity data; clinician and family involvement; missed or shortened rehabilitation sessions; perceived autonomy; and whether digital rehabilitation activities were experienced as transferring to meaningful activities of daily living. Participant identifiers P01–P14 were used to link accounts to the analytic dataset while avoiding the use of participant names in the reported findings.

Data Analysis

Data were analyzed iteratively using reflexive thematic analysis following the principles described by Braun and Clarke (22). Analysis involved repeated familiarization with participant accounts, generation of initial codes, examination of relationships among codes, development of candidate themes, comparison of candidate themes with the wider dataset, refinement of theme boundaries, and construction of an interpretive account of sustained engagement.

Coding addressed both explicit experiences and their underlying meaning within rehabilitation. Semantic material included practical problems such as charging devices, positioning sensors, managing applications, and tolerating wearable or VR equipment. More interpretive coding considered experiences such as feeling supported by feedback, feeling judged by numerical targets, perceiving technology as meaningful or repetitive, and negotiating independence alongside clinician or family involvement. Particular attention was given to variation over time, internally contradictory experiences, and accounts that did not fit the dominant pattern because engagement was conceptualized as dynamic rather than as a fixed characteristic of the participant.

Rigour and Reflexivity

Analytic rigour was supported through a structured audit trail linking codes, candidate themes, theme refinement, and the final interpretive account. Attention was given to disconfirming and contrasting participant accounts rather than treating repeated technology use as inherently beneficial or interpreting reduced use automatically as poor motivation. Reflexive consideration was also given to assumptions that digital technologies are intrinsically engaging and that greater device use necessarily represents better rehabilitation. Participant accounts were interpreted in relation to differences in impairment, previous rehabilitation experience, family support, digital confidence, and expectations of recovery.

Ethical Considerations

Ethical approval for the study was obtained from Universitas Prima Indonesia.

RESULTS

Participant Characteristics

Fourteen adults aged 45–76 years who were 3–24 months post-stroke were represented in the study. Participants differed in sex, time since stroke, primary rehabilitation focus, and reported level of digital confidence. Six participants had an upper-limb rehabilitation focus, five had a gait/balance focus, and three had mixed rehabilitation needs. Digital confidence ranged from low to high, providing variation in participants' prior comfort with technology.

Table 1. Participant Characteristics

Participant	Age, years	Sex	Months Post-Stroke	Primary Rehabilitation Focus	Digital Confidence
P01	58	M	8	Upper limb	Moderate
P02	64	F	14	Gait/balance	Low
P03	49	M	5	Upper limb	High
P04	71	F	18	Gait/balance	Low
P05	55	M	10	Upper limb	Moderate
P06	62	M	7	Mixed	Moderate
P07	45	F	4	Upper limb	High
P08	76	M	24	Gait/balance	Low
P09	67	F	12	Mixed	Moderate
P10	53	M	6	Upper limb	High
P11	60	F	9	Gait/balance	Moderate
P12	69	M	20	Mixed	Low
P13	51	F	11	Upper limb	High
P14	73	M	16	Gait/balance	Moderate

Analysis generated four interrelated themes describing the transition from initial enthusiasm toward continued, modified, or reduced engagement with digitally supported rehabilitation: (1) novelty had to become personally meaningful progress; (2) technical and bodily friction accumulated over time; (3) data could motivate, pressure, or confuse; and (4) human scaffolding sustained autonomy rather than replacing it. Across the themes, engagement was characterized by repeated evaluation of whether the perceived rehabilitation value of the technology justified the effort required to continue using it.

Theme 1: Novelty Had to Become Personally Meaningful Progress

Initial engagement was frequently associated with curiosity and the interactive nature of VR, but novelty alone did not appear sufficient to sustain continued use. Participants described becoming more selective over time and increasingly judging digital exercises according to whether improvement within the system corresponded with activities that mattered outside it. P01 described a shift from using VR because it was new toward evaluating whether continued practice was improving hand function needed at home.

Perceived progress did not need to be dramatic, but it needed to be understandable and functionally meaningful. Improvements in scores, speed, grip, or movement became more valuable when participants could connect them with changes in everyday activity. Conversely, repetition without an accompanying sense of meaningful progress reduced enthusiasm. P08 described the technology as becoming less exciting when repeated practice no longer felt different from using an ordinary exercise device.

The level of challenge also influenced continued engagement. Participants valued progression when it demonstrated improvement without repeatedly confronting them with tasks that remained unattainable. P07 described appreciating small increases in difficulty because progression made improvement visible while retaining a sense that the next level remained achievable. These accounts suggested that sustained engagement depended less on entertainment alone than on whether the technology communicated a credible trajectory toward personally relevant functional improvement.

Theme 2: Technical and Bodily Friction Accumulated Over Time

Participants described the practical demands of digital rehabilitation as cumulative. Individual activities such as charging devices, positioning sensors, opening applications, reconnecting equipment, or correcting failed movement detection could appear minor when considered separately but became burdensome when repeated within everyday rehabilitation routines. P02 explained that the combined sequence of charging, connecting, and troubleshooting could consume energy before the rehabilitation exercise itself had begun.

Post-stroke fatigue intensified this distinction between therapeutic effort and avoidable technological effort. Participants generally accepted exertion associated with rehabilitation exercises more readily than fatigue caused by device setup or troubleshooting. P06 described frustration when time and energy intended for exercise were instead consumed by repairing or configuring equipment. Physical comfort also influenced continued use. P11 reported shortening wearable use when the strap caused skin irritation.

VR-related discomfort varied across participants. Some described visual strain, heat, heaviness, or balance-related discomfort that led them to shorten or modify sessions rather than abandon the technology completely. P04 reported being able to complete the movements but needing to rest quietly after approximately 20 minutes because of a heavy sensation in the head. These accounts indicated that reduced or interrupted use could represent an adaptive response to fatigue or discomfort rather than a simple absence of motivation.

Theme 3: Data Could Motivate, Pressure, or Confuse

Wearable-generated data gave some participants a more visible representation of rehabilitation activity outside formal therapy sessions. For these participants, counts, graphs, or trends made otherwise subtle changes easier to recognize. P05 described comparing activity patterns between days and using visible improvement as encouragement to repeat behaviors associated with a better day.

The same metrics could become burdensome when numerical targets were interpreted as rigid expectations. P09 described feeling that failure to reach a target functioned like a negative judgement even on days affected by fatigue or other commitments. Participants also questioned data when device measurements did not correspond with their own experience of activity. P12 described uncertainty when a wearable indicated low activity despite participation in household activity that morning, raising questions about whether the device had failed to detect meaningful movement.

Clinical interpretation changed how some participants understood these data. P13 described moving away from pursuing an isolated daily target after a therapist helped interpret activity as a longer-term pattern. The participant subsequently experienced the data more as guidance than as a test. Across these accounts, wearable feedback appeared most meaningful when participants could understand what the metric represented, recognize its limitations, and interpret variation within the context of their own rehabilitation and daily circumstances.

Theme 4: Human Scaffolding Sustained Autonomy Rather Than Replacing It

Participants did not describe technology and professional support as competing alternatives. Continued technology use was more readily integrated into rehabilitation when clinicians could personalize tasks, help resolve barriers, interpret feedback, and modify the rehabilitation plan as participants' capacities changed. P14 explained that constant therapist presence was unnecessary but that continued confidence depended on knowing that the plan could be reviewed and adjusted when it no longer suited current needs.

Family involvement could similarly reduce practical burden, particularly when participants experienced difficulty managing devices because of physical impairment. However, participants distinguished supportive assistance from excessive supervision. Help was perceived more positively when it facilitated setup or reduced technical demands without transforming rehabilitation targets into household monitoring or pressure.

Across the themes, autonomy did not mean being left to manage digital rehabilitation without support. Participants valued the ability to choose the timing, intensity, and practical organization of rehabilitation

while retaining access to responsive professional input. Sustained engagement therefore appeared to depend on a balance between structure and flexibility: sufficient guidance to maintain relevance, sufficient adaptability to accommodate changing physical capacity, and sufficient human interpretation to prevent technology-generated metrics from becoming the sole determinant of rehabilitation progress.

DISCUSSION

This qualitative study explored sustained engagement with VR- and wearable-supported rehabilitation after stroke by shifting attention from initial technological acceptability toward the conditions under which continued use remained worthwhile. The four themes collectively indicated that engagement was dynamic rather than a stable characteristic of the individual. Participants repeatedly evaluated whether the functional and motivational value of digital rehabilitation justified the physical, technical, cognitive, and organizational demands associated with continued use. This interpretation is consistent with previous qualitative evidence showing that stroke survivors may value feedback, enjoyment, challenge, immersion, and increased opportunities for practice while simultaneously experiencing fatigue, technical difficulties, frustration, monotony, discomfort, and inadequate personalization (13–17). Research on home-based telerehabilitation similarly suggests that technology acceptance depends on perceived usefulness, confidence, support, and compatibility with daily routines rather than on technological availability alone (18).

The first theme demonstrated that novelty was most useful as an entry point rather than as a durable mechanism for maintaining rehabilitation behavior. Participants became increasingly interested in whether improvement within the virtual environment corresponded with meaningful changes in daily function. This finding is compatible with contemporary rehabilitation frameworks that emphasize task-specific, progressive, and meaningful practice and with evidence showing that VR may be beneficial when integrated into conventional stroke rehabilitation rather than treated as an isolated technological intervention (2–7). Previous qualitative studies have also shown that enjoyment and immediate feedback can support participation, whereas repetitive or poorly individualized activities may weaken engagement over time (13–17). The present findings extend this interpretation by suggesting that perceived functional transfer may become more important than entertainment as experience with the technology increases. Digital rehabilitation platforms may therefore be more sustainable when progression within the system remains visibly connected to activities that users consider important.

The second theme highlighted the cumulative nature of technical and bodily friction. Participants did not necessarily reject rehabilitation because it required effort; instead, they distinguished therapeutic effort from avoidable effort associated with charging, configuring, positioning, reconnecting, or troubleshooting devices. This distinction is particularly relevant after stroke, where fatigue and functional limitations can already interfere with continued rehabilitation activity after discharge (19). Reviews and feasibility studies of wearable-supported and home-based rehabilitation have similarly identified usability, comfort, device management, technical support, and practical integration into everyday life as important determinants of continued use (8,12,18). The findings therefore caution against interpreting missed, shortened, or modified sessions automatically as lack of motivation or poor adherence. In some circumstances, reduced use may represent an adaptive response to symptom burden, discomfort, or excessive technological demands.

The third theme demonstrated that wearable-generated information could have contrasting effects depending on how participants understood and contextualized it. Activity counts, graphs, and performance trends could make progress more visible and strengthen a sense of agency, but numerical targets could also become discouraging when they failed to account for fatigue, competing activities, measurement limitations, or day-to-day variability. Wearable technologies are increasingly used to measure mobility, gait, upper-limb activity, and physical activity after stroke, yet reviews continue to identify challenges relating to measurement validity, usability, interpretation, and integration of generated data into rehabilitation practice (8–10). The present accounts suggest that the value of continuous monitoring does not depend solely on the volume of information collected. Feedback appeared more constructive when

participants understood what a metric represented, recognized its limitations, and could interpret variation over time rather than treating individual daily values as definitive judgements of rehabilitation success.

Clinical interpretation was particularly important in changing the meaning of wearable-generated data. Participants described numerical information more positively when clinicians contextualized fluctuations, adjusted expectations, and connected metrics with broader rehabilitation goals. This finding supports a view of digital rehabilitation in which technology complements rather than replaces professional interpretation. Guidance for virtual stroke rehabilitation similarly emphasizes appropriate assessment, training, monitoring, adaptation, and access to professional support when care is delivered through digital modalities (23). Human input may therefore help maintain the informational value of monitoring while reducing the risk that decontextualized targets are experienced as surveillance or failure. The implication is not that every digital rehabilitation session requires direct therapist supervision, but that users should retain access to responsive clinical interpretation when goals, symptoms, functional capacity, or technology performance change.

The fourth theme further indicated that autonomy and human support were not mutually exclusive. Participants valued being able to decide when and how rehabilitation occurred while retaining access to clinicians who could modify tasks, interpret feedback, or resolve barriers. Family assistance could also reduce practical burden, particularly where physical impairment made device management difficult, but excessive monitoring risked diminishing participants' sense of ownership. These accounts are consistent with evidence that successful home-based digital rehabilitation depends on the interaction among usability, confidence, personal relevance, technical assistance, and professional or family support (12,18,23). Supported autonomy may therefore represent a more appropriate goal than completely unsupported self-management: sufficient flexibility to accommodate changing capacity, combined with sufficient guidance to ensure that technology remains connected with meaningful rehabilitation objectives.

Taken together, the findings suggest that sustained engagement should be considered an important implementation outcome in its own right rather than being inferred from initial enthusiasm, usability scores, or simple counts of completed sessions. Digital rehabilitation programs are increasingly being considered as mechanisms for extending rehabilitation beyond conventional clinical environments, but equitable implementation also requires attention to technology access, digital confidence, equipment burden, internet reliability, clinical support, and the resources needed to interpret remotely generated data (23,24). The present findings indicate that long-term engagement may be strengthened when systems minimize avoidable setup demands, allow flexible dosing, communicate progress in understandable ways, and maintain a clear connection between digital performance and activities that are meaningful to the individual. These implications should be interpreted as qualitative, hypothesis-generating insights rather than evidence that any particular digital design strategy will independently improve clinical outcomes.

Several limitations should be considered when interpreting these findings. The study involved a purposively selected sample of 14 adults with prior experience of both VR and wearable-supported rehabilitation, and the accounts therefore represent the experiences of this specific qualitative sample rather than population-level estimates. Participants differed in age, stroke chronicity, rehabilitation focus, and digital confidence, which increased experiential variation but also meant that experiences occurred across heterogeneous technological and functional circumstances. The analysis relied on participant accounts and did not independently measure device adherence, functional improvement, or the accuracy of wearable-generated metrics. Individuals who were able to discuss at least four weeks of digitally supported rehabilitation may also differ from stroke survivors who discontinued technology earlier, were unable to access such systems, or experienced communication barriers. Consistent with qualitative reporting principles, the findings should therefore be interpreted in terms of contextual meaning and transferability rather than statistical generalizability (20,21).

Future research should investigate sustained engagement longitudinally and integrate qualitative accounts with device-use records, changing rehabilitation goals, symptoms, functional outcomes, and patterns of

clinician interaction. Mixed-method approaches could help distinguish temporary reductions in use caused by fatigue or technical barriers from disengagement associated with declining perceived value. Studies should also examine how engagement differs across levels of impairment, digital confidence, socioeconomic circumstances, home environments, caregiver availability, and types of VR or wearable systems. Such work may clarify which aspects of personalization, feedback, technical support, and professional involvement are most important for maintaining meaningful participation beyond the initial period of technology adoption (8,15,18,23,24).

CONCLUSION

Sustained engagement with VR- and wearable-supported rehabilitation after stroke was shaped less by technological novelty than by whether continued use remained meaningful, manageable, interpretable, and responsive to changing rehabilitation needs. Participants valued visible functional progress, adaptable challenge, flexible home practice, and data that could be understood in context, while engagement weakened when technical burden, fatigue, discomfort, repetition, or poorly interpreted metrics outweighed perceived benefit. Autonomy was strongest when participants retained control over their rehabilitation routines while still having access to responsive clinical and appropriate family support. These findings suggest that sustained engagement should be treated as a dynamic rehabilitation outcome rather than as a simple proxy for motivation or compliance, and that digital rehabilitation systems are more likely to remain useful when they minimize avoidable friction and maintain a clear connection between technology-supported activity and personally meaningful functional goals.

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