What do Healthcare Professionals Need? An Online Study on Personalized Virtual Reality for Stroke Recovery at a Rehabilitation Center

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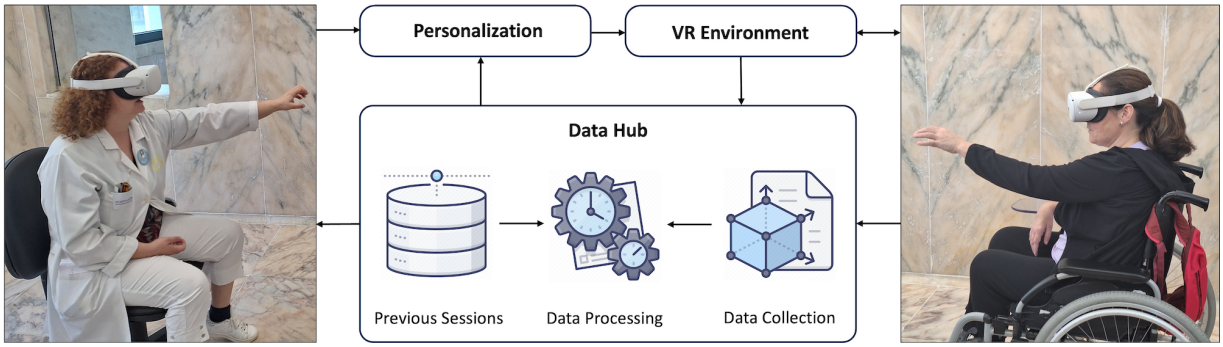

Figure 1: Conceptual model outlining the integration of Virtual Reality (VR) with personalization to support the recovery of stroke survivors. The process begins with the collection of data, capturing both stroke survivor-specific metrics and the current state of the virtual environment. This data will inform adaptive mechanisms that tailor the VR experience, responding to each survivor's progress. This model can also enable empower healthcare professionals to make informed adjustments to the rehabilitation process as needed.

Abstract

Rehabilitation is paramount for stroke recovery, yet traditional methods have recognized limitations, like using repetitive exercises, with a lack of personalization. These can lead to decreased motivation and hinder long-term progress. Furthermore, each stroke survivor presents unique needs and constraints, which are rarely addressed in standardized rehabilitation protocols. This work explores the potential of Virtual Reality (VR) serious games to support stroke rehabilitation by offering personalized experiences tailored to individual progress. To better understand the practical requirements and expectations for implementing such solutions, an online survey was conducted among 10 healthcare professionals from a rehabilitation center. Results highlight that 70% of participants preferred a hybrid personalization mode, combining automated and manual adjustments. For synchronization, 50% favored a hybrid approach, while 40% preferred real-time (synchronous) updates. According to the questionnaire responses on personalization, the most valued data type was motivation (70%), followed by emotional state and reaction to stimuli (60% each). Key VR features included adaptable environments and feedback when users are confused (both with 60%), along with dynamic task difficulty adjustment and adaptation to the survivor's clinical state (50% each). These insights provide a foundation for developing more effective and engaging rehabilitation tools using VR, paving the way for more human-centered stroke recovery programs.

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1 Introduction

Stroke is a medical condition that occurs when the blood supply to part of the brain is interrupted or reduced, preventing brain tissue from receiving oxygen and nutrients. This can result in brain cell damage or death within minutes, leading to a wide range of physical, cognitive, and emotional impairments. Strokes are typically classified as ischemic (caused by blocked arteries) or hemorrhagic (caused by bleeding in the brain), with both types posing serious health risks [13, 26, 27].

According to the World Health Organization (WHO)[1], stroke affects approximately 15 million people worldwide each year. Of these, around 5 million die, and another 5 million are left permanently disabled, making stroke one of the leading causes of long-term disability globally [16,31]. Stroke survivors often experience a range of limitations, which may include partial or complete paralysis, impaired speech, difficulty in movement coordination, memory loss, and challenges in performing daily activities. These impairments can significantly affect the quality of life, independence, and psychological well-being of the survivors, necessitating ongoing and structured rehabilitation [5, 19, 20].

To address these challenges, rehabilitation plays a vital role in helping stroke survivors regain functional abilities and adapt to life after the stroke [2, 21]. Rehabilitation can take various forms, including physical therapy, occupational therapy, speech and language therapy, and cognitive training. These interventions are typically conducted in clinical settings, rehabilitation centers, or even at home with remote supervision [3, 7, 10]. However, traditional rehabilitation approaches, especially those focusing on physical and cognitive aspects, often suffer from limitations. These include the repetitive

[1]https://www.who.int

and monotonous nature of exercises and the lack of individualized adaptation [28, 30]. Most programs adopt a one-size-fits-all model, despite the fact that every stroke survivor has unique needs, preferences, and recovery trajectories [18, 22, 24].

This lack of personalization and variety can lead to decreased motivation and engagement among stroke survivors. Over time, this may result in a reduced willingness to continue with the rehabilitation process, increased frustration, and in some cases, the onset of depression [12, 15, 29]. Ensuring long-term adherence to rehabilitation is thus a significant concern for healthcare providers. Therefore, it is crucial to explore how personalization can be effectively integrated into stroke rehabilitation [5, 23]. By tailoring rehabilitation experiences to individual needs and progress, it is possible to foster greater interest and engagement in the process, ultimately improving outcomes and enhancing the survivor's overall quality of life.

In this context, our work proposes the use of Virtual Reality (VR) Serious Games as a promising solution for stroke rehabilitation. Recent literature has highlighted the potential of VR in this domain, showing that it can increase motivation, support the correct execution of specific gestures, and offer immersive and stimulating environments that capture the user's attention [5, 19]. Specifically, we focus on how these virtual environments can be personalized to suit the needs of individual stroke survivors. Since each person recovers at their own pace and has distinct physical and cognitive capacities, it is essential that VR-based rehabilitation tools are adaptable and responsive to each user's performance and progress.

Given the limited research available on personalization in VR-based rehabilitation, we began by designing an online survey targeting healthcare professionals. They are key stakeholders in the rehabilitation process, as they are responsible for monitoring stroke survivors progress and configuring therapeutic interventions. Their insights are crucial for identifying personalization requirements and bridging the gap between clinical practice and technological innovation. Through this approach, we aim to take a first step toward understanding how personalization can be meaningfully integrated into VR-based stroke rehabilitation. Our ultimate goal is to propose a framework that supports the development and deployment of personalized serious games in rehabilitation centers, enhancing the therapeutic experience and effectiveness for stroke survivors.

The rest of the paper is organized as follows: Section 2 details the methods and materials used. Section 3 presents the main insights obtained. Next, Section 4 describes the study limitations and opportunities for further work. Finally, Section 5 concludes by summarizing the main outcomes.

2 Methods and Materials

This section describes the methods and materials considered towards understanding the needs of healthcare professionals regarding the personalization of VR-based environments for stroke rehabilitation.

2.1 Study goals

Stroke is the leading cause of death and disability among adults in Portugal. Every hour, three people suffer a stroke, one of whom will not survive. For those who survive, the consequences can be life-changing, affecting not only their own lives but also the lives of their caregivers, who must adjust to new roles and responsibilities [1,8,14]. Therefore, rehabilitation is a vital component in post-stroke care, supporting individuals in recovering lost abilities.

This work aims to explore how virtual environments can be personalized during the rehabilitation process of stroke survivors, with the goal of increasing long-term motivation and engagement. Given that stroke rehabilitation often requires individuals to undergo numerous and repetitive sessions, integrating personalization into virtual experiences can help make the process more meaningful, adaptive, and aligned with individual progress and needs. Since the existing literature on personalization in VR-based stroke rehabilitation is still relatively new, and considering the unique characteristics and vulnerabilities of the target audience, it becomes essential to investigate what types of personalization are both effective and practical for stroke survivors. Equally important is understanding how these personalization strategies can be successfully implemented by healthcare professionals in real-world settings, ensuring that technological innovation remains grounded in clinical relevance.

2.2 Methodology

To help achieve the intended goals, a Human-Centered Design (HCD) methodology was adopted. Leveraging a long-standing collaboration with a renowned rehabilitation center, active since 2016, a multidisciplinary team was assembled to explore how personalization in virtual environments could be effectively implemented and managed within clinical settings. The focus was to understand the practical dynamics of a rehabilitation context, identify who should be responsible for customizing the rehabilitation experience, and ensure that any technological solution would seamlessly integrate into existing therapeutic routines.

This team brought together domain experts in Human-Centered Computing (HCC), with deep knowledge in VR, 3D user interfaces, user experience design, and user studies. A key contributor was a medical doctor and rehabilitation specialist, a former director of the rehabilitation center, with decades of clinical experience and a thorough understanding of the needs and challenges faced by both stroke survivors and healthcare professionals.

By embracing an HCD approach, this work sought to engage healthcare professionals directly, gathering valuable input about their daily tasks, challenges, and expectations. This process is essential to define the functional and technical requirements of the system. These requirements will serve as the foundation for the design and development of an initial prototype. As development progresses, the involvement of the target users will remain central, helping to refine the prototype through iterative testing and feedback, ensuring that in time, it aligns closely with their clinical realities and the goals of personalized stroke rehabilitation.

2.3 Target users and procedure

After consulting with our collaborator from the rehabilitation center and gaining a deeper understanding of the clinical workflow and dynamics, the research team concluded that, while stroke survivors are the ultimate beneficiaries of personalized rehabilitation, healthcare professionals are the ones who will determine how personalization is implemented. Their clinical expertise, familiarity with survivors progress, and direct involvement in therapeutic interventions place them in a critical position to decide what elements should be adjusted and how frequently such adaptations should occur.

As a result, healthcare professionals were identified as the initial target group to consult in order to gather insights on what aspects of virtual environments should be personalized to best align with the rehabilitation needs of stroke survivors. Their frontline experience makes them uniquely equipped to highlight key features that must be tailored, and to foresee practical constraints and opportunities that could influence the deployment of VR-based rehabilitation tools in a clinical setting.

In line with this decision, the research team opted to design and deploy a questionnaire as the primary method for data collection. Surveys are a widely adopted tool across diverse domains, including healthcare and industry, due to their efficiency in gathering structured feedback from a specific user group [4, 6, 9, 11, 17, 25]. This approach allows researchers to systematically capture preferences, experiences, and opinions, which can then be analyzed to establish foundational requirements. These requirements will inform the design of a VR-based prototype tailored to clinical realities, ensuring that future development is grounded in the needs and expectations of those responsible for guiding rehabilitation processes.

2.4 Data Collection

Given the absence of any existing survey instruments in the literature related to personalization in VR-based stroke rehabilitation, the research team opted to design a new questionnaire from the ground up. The process began by outlining the key areas of understanding we aimed to explore. From there, an initial set of questions was drafted, which went through several refinement cycles across team meetings, ultimately being narrowed down to a more concise and manageable set of questions suitable for our target audience.

It was important to ensure that the questionnaire was not overly exhaustive, recognizing that healthcare professionals have demanding responsibilities and limited availability during their workday. Therefore, the survey was designed to be brief yet insightful. To further support participation and clarify any doubts, our member from the center accompanied while participants completed the questionnaire. This not only provided real-time assistance, if needed, but also allowed to observe the interaction with the survey and make any necessary adjustments early in the process.

From a logistical standpoint, to simplify distribution and facilitate potential deployment in other centers in the future, the survey was made available online using a multi-platform format. This ensured compatibility with a variety of devices (e.g., desktop, tablet, or smartphone) and allowed data to be automatically collected in digital format. Such an approach streamlined the process of aggregation, visualization, and analysis, helping the research team to interpret responses more efficiently.

As for the structure of the online survey itself, it opened with a brief explanation of the study's objectives, ensuring participants were informed about the purpose of the research. Participants were also notified that, by responding to the questionnaire, they were providing informed consent for their anonymized data to be used for research purposes. The survey could then be completed at each participant's own pace, ensuring thoughtful and voluntary engagement.

The survey included a series of demographic and professional background questions (e.g., years of experience, time working at the center, prior exposure with VR, among others. See Table 1). In addition, six targeted questions addressed specific aspects of personalization within virtual environments for stroke rehabilitation, some of which included multiple-choice options to support participants in identifying their preferences more easily. The questionnaire concluded with an open-ended question, inviting participants to share any additional thoughts, concerns, or suggestions they considered relevant to the topic.

Table 1: Illustration of the questions used in the online survey, covering demographic information, prior experience with digital realities, perceived challenges in delivering personalized rehabilitation, and specific questions aimed at identifying how virtual environments can be personalized to support stroke recovery.

Category	Questions (Q)
Demographic data	Q1. What is your age? Q2. What is your gender? Q3. How many years have you been in the profession/field? Q4. How many years have you worked at the rehabilitation center? Q5. Professional group to which you belong?
Prior experience with digital realities	Q6. Have you ever used virtual reality technologies? Q7. Have you ever used augmented reality technologies?
Personalized rehabilitation challenges	Q8. What are the main challenges in personalized rehabilitation? Q9. How do you adapt therapies to the individual needs of each survivor (when possible)? Q10. What kind of data about the survivor would be important to help personalize the rehabilitation process?
Personalized VR for rehabilitation	Q11. Which personalization mode do you find most interesting? Q12. Which personalization synchronization mode do you consider most important? Q13. What features could make the use of Virtual Reality environments more adapted to the needs of each survivor? Q14. Add any other suggestions or comments you feel are necessary.

3 Results

This section describes the participant sample and outlines the main insights obtained through the online survey, allowing to understand what are the preferences of healthcare professionals regarding the personalization of VR-based environments for stroke rehabilitation.

3.1 Participants

A total of 10 healthcare professionals participated in the study (see Table 2), with the majority being female (9 participants, 90%) and one male (10%). Participants' ages ranged from 30 to 59 years old, with most falling within the 30–49 age interval. The sample included a diverse group of professionals from the rehabilitation center, encompassing physicians, nurses, physiotherapists, and a speech therapist. Most participants had extensive experience in their respective fields, with several reporting over 20 years of professional practice. Time spent working at the rehabilitation center also varied, with a notable number having been at the institution for over a decade. In terms of familiarity with VR, most participants had some level of experience, having previously taken part in user studies where this technology was deployed. Several also reported accompanying stroke survivors during both individual and collaborative VR-based rehabilitation sessions. Only two participants indicated having no experience with this technology.

3.2 Answers to the online survey

Next, participants' responses to the online survey (Q8-Q14) are presented in detail, providing the foundation for identifying key requirements and informing the design of future personalized VR-based rehabilitation. Table 3 summarizes each of the questions, the answer options, and the respective number of votes obtained.

3.2.1 Q8 - What are the main challenges in personalized rehabilitation?

The first question aimed to identify the main challenges professionals face when implementing personalized rehabilitation for survivors.

One of the most voted challenges was ***cognitive changes*** with 9/10 votes, emphasizing how issues such as attention deficits, memory loss, or reduced problem-solving capacity can disrupt engagement and responsiveness to interventions. These challenges require greater flexibility and creativity in designing therapeutic activities.

Equally mentioned in 9 responses was ***communication difficulties***. This reflects a consistent concern that many stroke survivors struggle with verbal expression or comprehension, which can hinder both their understanding of therapeutic goals and their ability to provide useful feedback—key elements for effective personalization.

Additionally, ***survivor's collaboration***, particularly related to their ability to express themselves, appeared in 5 responses. This indicates that even beyond formal communication issues, survivors may struggle to actively participate in therapy, making it harder for professionals to co-design appropriate activities or adapt on the fly.

Difficulty in maintaining interest was highlighted in 4 responses. While not as dominant as cognitive or communication concerns, this still points to a need for personalized motivational elements, perhaps through gamification or emotionally engaging feedback to sustain long-term rehabilitation efforts.

Moreover, ***fatigue*** was noted in 3 responses, illustrating that survivors often have limited stamina, which constrains the frequency,

Table 2: Demographic overview of the healthcare professionals who participated in the online survey, including age group, gender, professional background, years of experience, time at the rehabilitation center, and level of familiarity with VR.

Variable	Response Option	N (%)
Age	23–29	0
	30–39	5 (50)
	40–49	4 (40)
	50–59	1 (10)
	60–70	0
Gender	Male	1 (10)
	Female	9 (90)
Professional background	Physician/Doctor	2 (20)
	Physiotherapist	1 (10)
	Occupational therapist	0
	Speech therapist	1 (10)
	Psychologist	0
	Nurse	6 (60)
Years in the profession	<1 year	0
	1–5 years	0
	6–10 years	2 (20)
	11–20 years	4 (40)
	21–30 years	4 (40)
	>30 years	0
Years working at the rehabilitation center	<1 year	0
	1–5 years	0
	6–10 years	4 (40)
	11–20 years	3 (30)
	21–30 years	3 (30)
	>30 years	0
Prior experience with VR	None	2 (20)
	Not much	6 (60)
	Some	2 (20)
	Much	0

duration, or intensity of personalized sessions. Tailored rest periods or adaptive pacing mechanisms might be necessary to manage this issue effectively.

Difficulty adjusting activity intensity was mentioned in only 1 response. Although less common, it still suggests that creating the right level of challenge, neither too easy nor too frustrating, can be a fine balance and is critical to individualized care. This does not mean it is less important; rather, it may be perceived as easier to implement compared to the remaining options.

Finally, ***lack of data to better understand the survivor's condition***, which may indicate that professionals do not have concerns about the insufficient data on the survivor's status.

3.2.2 Q9 - How do you adapt therapies to the individual needs of each survivor (when possible)?

This question aimed to explore how professionals personalize rehabilitation approaches based on the unique characteristics and conditions of each stroke survivor.

One of the options most voted was the ***ability to concentrate***, with 6 votes. This indicates that professionals usually adjust therapy by considering the survivor's ability to focus or maintain attention to maximize recovery and minimize frustration.

Likewise, the ***survivor engagement*** was also top rated, having obtained 6 votes. This suggests that the survivor's active participation and motivation directly influence how rehabilitation is tailored, as it influences survivor's sense of empowerment and ownership over the recovery process.

Also with 6 responses, is the ***difficulty of expression***. This reflects concerns with verbal or non-verbal communication limitations, likely leading to adapted language or instruction methods.

Table 3: Illustration of the questions used in the online survey, from Q8 to Q13, including the respective answer options and number of votes associated.

Question (Q)	Response Option	N
Q8 - What are the main challenges in personalized rehabilitation?	Cognitive changes	9
	Communication difficulties	9
	Survivor's collaboration	5
	Maintaining interest	4
	Fatigue	3
	Difficulty adjusting activity intensity	1
Q9 - How do you adapt therapies to the individual needs of each survivor (when possible)?	Ability to concentrate	6
	Survivor engagement	6
	Difficulty of expression	6
	Cognitive changes	6
	Fatigue	3
Q10 - What kind of data about the survivor would be important to help personalize the rehabilitation process?	Motivation	7
	Reaction time to stimuli	6
	Emotional state	6
	Duration of exercise	5
	Pain reported during exercise	5
	Muscle strength	4
	Tiredness shown	3
	Satisfaction	3
Q11 - Which personalization mode do you find most interesting?	Hybrid	7
	Manual	3
	Automatic	0
Q12 - Which personalization synchronization mode do you consider most important?	Hybrid	5
	Synchronous	4
	Asynchronous	1
Q13 - What features could make the use of Virtual Reality environments more adapted to the needs of each survivor?	Adapting characteristics of the virtual environment in which the survivor is inserted	6
	Inclusion of motivational objectives and personalized rewards	5
	Adjusting the difficulty of each activity	5
	Adapting to survivor's clinical characteristics	5
	Integration of rest/relaxation periods in neutral environments	4
	Feedback if survivor is lost or confused	4
	Adaptation to survivor's emotional state	2
	Personalization of the degree of precision to complete actions	2
	Customization of avatars in the virtual environment	1
	Changing the sequence of tasks	0

Equally important is ***cognitive changes***, having obtained 6 out of 10 answers. This highlights a frequent need to adapt tasks to memory, attention, or reasoning deficits. Professionals need to tailor exercises by adjusting instructions and complexity, while promoting continuous progression.

The option with less votes was ***fatigue***, selected by only by 30% of healthcare professionals. This may indicate that it is less often considered when personalizing therapy. Moreover, it may also indicate that it is a difficult element to consider for personalization.

3.2.3 Q10 - What kind of data about the survivor would be important to help personalize the rehabilitation process?

The purpose of this question was to identify the data that professionals consider essential for customizing rehabilitation programs.

Motivation was selected by 7 of the 10 professionals as an important information to personalize. This may be related to the fact that high motivation usually leads to more engagement and adherence to the rehabilitation process, improving the overall recovery. By having access to this survivors state, professionals can adapt the session and create more motivating exercises if necessary.

Another relevant option was ***reaction time to stimuli***, voted by 6 of the 10. The reaction time measures cognitive and motor performance. It was considered important because having access to this information, it may be possible to adapt the complexity of the exercises accordingly.

Professionals also considered important having access to the ***emotional state***, voted by 6/10, since it affects participation and progress. In this case, they can, for example, adjust the communication style according to the emotional state of the survivor.

The ***duration of exercise*** and the ***pain reported during exercise*** were both voted for by 5 out of 10. These factors may reflect the limits of the survivors and the consequent need to adjust the duration or intensity of the task.

Although ***muscle strength*** is an essential component of physical rehabilitation, it was considered an important factor to personalize by only 4 professionals. This suggests that although in traditional rehabilitation, muscle strength can be assessed periodically, it is not considered consistently in the ongoing adaptation of rehabilitation activities.

The least voted options were the ***tiredness shown*** and ***satisfaction***, with 3 answers. Which may be related to the fact that, although those are important factors to consider, they may not be as significant for the professionals to address when adapting the rehabilitation process.

The responses suggest that healthcare professionals, by placing great importance on motivation and emotional state, not only value survivors' physical abilities but also consider their emotional and cognitive readiness paramount.

3.2.4 Q11 - Which personalization mode do you find most interesting?

With this question, the intention was to find out which mode of personalization the healthcare professionals would find most beneficial (see Figure 2).

The option with the highest number of votes (7 out of 10) was the ***hybrid***, in which adaptation is done automatically by the system, but with the possibility for the health professionals to adjust whenever necessary. This may indicate that although professionals recognize technology as a support tool, they still prefer to retain clinical decision-making and not apply it as a replacement.

For 3 of the 10 votes, the preferred mode was ***manual***, being the adaptation performed by the healthcare professional. Professionals may prefer this mode because it feels more transparent and predictable, minimizing concerns about system decisions that lack human control.

Regarding the ***automatic*** mode, carried out by the system without the intervention of a healthcare professional, none of the participants chose this option. This suggests that no professional wanted to have a system that personalized therapy exclusively automatically, probably for the same reasons as the manual mode was selected by only 3. This choice might reflect a higher level of confidence in human-guided approaches, where the adaptation process is more transparent for the professionals.

3.2.5 Q12 - Which personalization synchronization mode do you consider most important?

This question assessed professionals' preferences on the timing of personalizing rehabilitation activities for stroke survivors. This question offered three synchronization modes as options: asynchronous, synchronous, and hybrid. In asynchronous mode, activities are adjusted before the session; in synchronous mode, adjustments occur in real time during the activity. The hybrid mode combines both approaches. Figure 3 reflects the options chosen by professionals.

The ***hybrid*** mode was the option most chosen, with 5 of the 10 votes. This can indicate a preference of the professionals for balancing immediate and post-session adjustments. Real-time adjustments

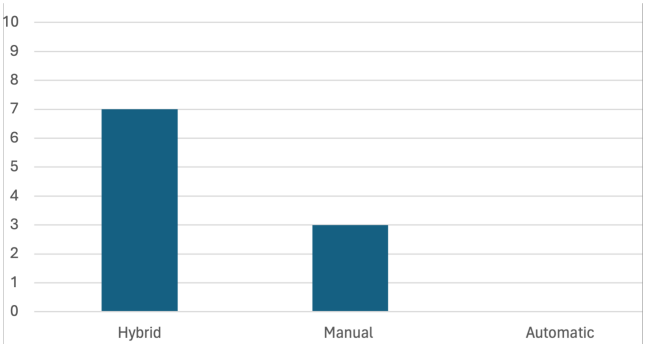

Figure 2: Distribution of participant votes for each personalization mode: hybrid (7); manual (3); automatic (0).

allow corrections to be made on the spot, while asynchronous enables a deeper analysis of the survivor's condition over time.

For 4 professionals, the preferred synchronization mode was ***synchronous*** since they can make adjustments at the moment according to the the survivors performance.

Regarding the ***asynchronous*** mode, it only had 1 vote, suggesting that it may consider late adaptation less effective, possibly because it lacks instant feedback and correction opportunities.

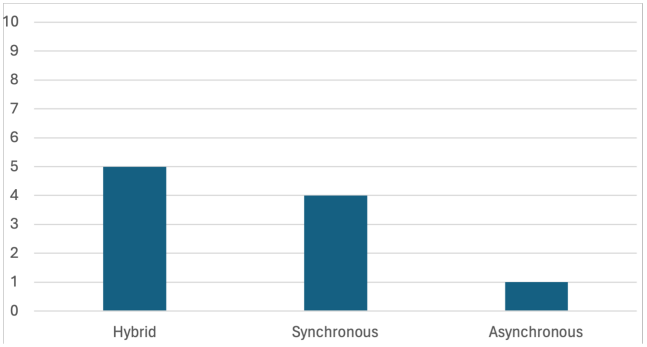

Figure 3: Distribution of participant votes for each personalization synchronization mode: hybrid (5); synchronous (4); asynchronous (1).

3.2.6 Q13 - What features could make the use of Virtual Reality environments more adapted to the needs of each survivor?

With this question, the goal was to determine which aspects of the VR rehabilitation system professionals consider relevant to adapt to the needs of stroke survivors. As before, some options were provided, and each individuals could choose more than one option.

Adapting the characteristics of the virtual environment in which the survivor will be inserted (e.g., changing objects or the theme of the environment, adjusting the sound volume, adapting the colors displayed, etc.) was one of the most voted options, with 6 out of 10. Allowing customization of themes and objects in the virtual environment can help align therapy with the survivor's personal preferences and familiar daily contexts. Additionally, unfamiliar or overly stimulating environments can lead to frustration or disorientation. The ability to adjust environmental elements supports the creation of a safer, more comfortable, and supportive therapy environment.

Also with 6 responses, was the option of providing ***feedback whenever the survivor is lost or confused about the objective of the activity to be carried out***. This may be because having guidance features helps make sure survivors don't get frustrated, by offering

support when they feel lost. This kind of assistance is especially important for stroke survivors, who may face challenges related to cognition or attention, making it harder to stay focused or understand instructions. Additionally, since many may not be tech-savvy, clear and timely guidance ensures they can navigate the VR environment with confidence and without feeling overwhelmed.

Adjusting the difficulty associated with each activity (e.g., reducing/increasing the number of objects to capture, etc.) was also highlighted by 5 professionals. The ability to dynamically adjust difficulty could allow the healthcare team to maintain an optimal challenge level. This aligns well with the core principles of serious games, which aim to balance challenge and skill to sustain engagement while achieving therapeutic goals.

Additionally, also with 5 responses was ***adapting to the survivor's characteristics***. This selection can be related to the fact that personalizing rehabilitation according to survivors characteristics ensures that interventions are relevant, feasible, and support each individual unique needs and progression rhythm. This also means that the VR system must be capable of storing and retrieving data from previous sessions, enabling continuous adaptation of the rehabilitation and supporting a more holistic approach to care.

Regarding the option ***integration of rest/relaxation periods in neutral environments***, this got 4 votes. Having support for rest can address mental fatigue during therapies. Creating a neutral environment between tasks can allow the body to recover from overstimulation. The absence of more votes may be due to the perception among professionals that this feature is more of a helpful suggestion than a core system requirement, something they can recommend or implement themselves without needing built-in system support.

The option of having ***inclusion of motivational objectives and personalized rewards*** was voted by 3 professionals. Incorporating motivational goals and personalized rewards can increase engagement and adherence, as it supports goal-oriented therapy and gives the survivor a sense of progress. Yet, this option was not rated among the most desired features, possibly because professionals prefer to be the ones providing verbal feedback and congratulations directly, fostering a more personal and human-centered interaction during therapy.

Adaptation to the survivor's emotional state was voted by only 2 professionals. This low preference may stem from the difficulty in accurately tracking emotional states in real time, which would likely require additional sensors or hardware. Such complexity might reduce the survivor's comfort or distract from the VR experience, potentially affecting engagement and immersion.

Moreover, ***personalization of the degree of precision required to complete actions*** was also selected by only 2 professionals. A similar reasoning may apply here, i.e., this level of personalization can be challenging to measure and calibrate. Additionally, since many stroke survivors naturally face precision difficulties, any level of accuracy could result in discouraging feedback, potentially affecting motivation and emotional well-being.

Customization of avatars in the virtual environment or the survivor's own avatar revealed to have low interest to the professionals, having only 1 vote. This may indicate that professionals do not prioritize personalizing the avatar's aesthetics. Instead, they seem to place greater value on functional aspects of therapy and the overall virtual environment. This is understandable, especially considering that many VR rehabilitation experiences are designed for first-person or task-focused interaction, where survivors rarely see their own avatar.

Regarding the option ***changing the sequence of tasks***, it had no votes, possibly because the professionals don't think that changing the sequence of tasks will affect the recovery itself.

3.2.7 **Q14 - Participants comments and suggestions.**

The open-ended responses provided by healthcare professionals offer valuable qualitative insights into how VR-based personalization can be meaningfully applied. Altogether, these insights underline the multifaceted nature of personalization in stroke rehabilitation and offer a rich foundation for designing VR solutions that are not only adaptive but also deeply human-centered.

A recurring theme was the importance of adapting rehabilitation activities to reflect survivors' previous routines, interests, and environment. These types of personal connections in VR can foster deeper engagement by making therapy feel more meaningful and contextually grounded. This could involve adjusting the complexity of instructions, tasks, and interface elements. For example, simulating tasks related to a survivor's past profession, hobbies, or everyday activities could help increase relevance and motivation. Some possibilities that a serious game could explore include simulating office tasks for a former administrative worker, gardening activities for someone who enjoys tending plants, or engaging with art in a virtual museum for those interested in culture and tourism. For instance, in the museum experience, survivors could explore exhibitions, interact with sculptures and paintings, and complete short quizzes to reinforce memory and attention skills. For leisure-oriented tasks, simple mini-games inspired by fairground activities, such as ring toss, fishing, or balloon popping, could be included, offering small rewards to maintain a sense of progression and achievement. To elaborate, in a personalized VR-based fair setting, mini-games could be tailored by adjusting difficulty and themes to match each survivor's abilities and interests. A ring toss game could use larger, closer targets for users with limited mobility, while a fishing game could reflect familiar environments and require progressively precise arm movements. A balloon-popping game could integrate memory tasks, with slower sequences and symbolic hints for those with cognitive challenges, each activity offering small rewards to reinforce progress and boost motivation. These familiar and enjoyable scenarios can be tailored to each survivor's interests and abilities, enhancing motivation and promoting engagement with therapy.

Given that upper limb impairment is a common consequence of stroke, another crucial suggestion for rehabilitation focused on movement quality rather than just task completion. Professionals emphasize that VR-based solutions should be able to assess and provide feedback not only on whether a task is completed but also on how it is performed. This would allow the healthcare team to personalize the VR experience (Figure 1), addressing compensatory movements that could lead to long-term issues, promoting more functional and safer recovery patterns. A VR-based serious game could address this need by incorporating features such as semi-transparent virtual guides that demonstrate the correct execution of specific movements. These visual aids could appear in real-time during exercises, helping stroke survivors replicate desired motion trajectories more accurately. By aligning their movements with the ghost hands, users receive immediate, intuitive guidance that encourages proper motor patterns while reducing the risk of developing compensatory habits. Additionally, the system could track deviations from the ideal motion and subtly adapt the guidance based on the survivor's abilities, ensuring that feedback remains supportive and achievable over time.

The feedback also emphasized the need to tailor the VR experience to the cognitive and educational level of each survivor. For instance, survivors with lower literacy levels might benefit from symbolic and visual guidance rather than written instructions. In line with this, professionals highlighted the importance of offering multimodal feedback (e.g., audible, visual, and symbolic) so that stroke survivors with varying cognitive and sensory abilities can better understand their progress. In fact, over the years, we have learned that only positive feedback should be provided, always aiming to boost motivation and sustain interest. Less favorable feedback can lead to discouragement and even depression, directly contradicting the supportive and empowering goals of rehabilitation. To accommodate all of these, instead of relying on text-heavy instruc-

tions, the VR-based game can use intuitive icons, animated tutorials, and voice-over guidance tailored to the survivor's comprehension level. Task complexity can also be dynamically adjusted based on user performance, ensuring that challenges remain achievable yet engaging. To reinforce motivation, non-playable characters (NPCs) within the virtual environment (whether human-like, animal-shaped, or robot-based) could deliver encouraging messages or celebrate small achievements, helping to create a more emotionally supportive experience. These elements, combined with personalized pacing and adaptive feedback styles, would foster a more accessible, enjoyable, and empowering rehabilitation journey.

Finally, the importance of involving family members was raised. This could be implemented by designing shared VR tasks in which other individuals, family, friends, and even other stroke survivors may be involved. Their engagement might increase the survivor's emotional support network and help with adherence to rehabilitation goals, fostering a sense of community and support, which is often vital in long-term recovery journeys. For example, cooperative mini-games could require survivors and other individuals to complete tasks together, such as cooking a virtual meal, navigating a maze, or assembling an object, each contributing different actions toward a shared goal. These tasks could be adjusted in difficulty based on each survivor's profile, ensuring accessibility and personalization. Competitive modes could also be designed in a supportive way, where points or achievements are shared and positive reinforcement is emphasized. This social layer not only enhances motivation but also reduces the sense of isolation that often accompanies rehabilitation, turning it into a shared, meaningful experience.

4 Limitations and Future Work

This section identifies some limitations, leading to potential areas for improvement and describes ideas for further research.

While the work presented here offers valuable insights and represents an important first step toward the future of personalized VR-based stroke rehabilitation, it is essential to acknowledge its limitations. One key limitation is that this initial investigation focused exclusively on healthcare professionals, without incorporating direct input from stroke survivors. This decision was guided by the research team's extensive experience in the field, and the clinical expertise of our collaborators at the rehabilitation center. Since the adoption and integration of novel technologies like VR in rehabilitation settings are typically mediated by healthcare professionals, it was deemed appropriate to begin with this stakeholder group. Nonetheless, a follow-up survey targeting stroke survivors is currently in preparation. It will be conducted on-site at the rehabilitation center, ensuring that participants are first introduced to and can interact with VR. This approach will allow stroke survivors to provide feedback based on actual experience rather than speculation, helping to ensure more informed and meaningful responses.

Additionally, despite involving domain experts from a renowned rehabilitation institution, the study's sample was relatively small, with only 10 participants. While this number can still yield valuable qualitative insights, it limits the generalization of the findings. A larger and more diverse sample would enhance the reliability of the results and allow for more robust conclusions about personalization needs and attitudes toward VR rehabilitation technologies across different healthcare roles and levels of experience.

Moreover, all participants were drawn from a single rehabilitation center, which may introduce institutional bias or reflect practices and perceptions specific to that center's culture and protocols. To address this, future work should expand the participant pool to include professionals from multiple institutions, ideally across different regions or healthcare systems. This would provide a broader perspective on personalization strategies, technology readiness, and practical implementation challenges, helping to inform the development of universally applicable VR-based rehabilitation solutions.

With the insights collected, the next step is to advance toward the creation of a first VR-based prototype that integrates the personalization elements highlighted as relevant by the healthcare professionals. To achieve this, it is essential to clearly define design and development priorities, ensuring that all stages of the process are closely guided and validated by our collaborators from the rehabilitation center. This collaborative and iterative approach will help guarantee that the resulting solution remains aligned with real-world needs and workflows. Once an initial version is completed, it will be necessary to organize a dedicated user study with the healthcare professionals, allowing them to test the personalization features, assess usability, and provide targeted feedback. Only after addressing this feedback and refining the prototype accordingly should the solution be introduced to stroke survivors. At that stage, the prototype will be more robust, and its relevance and readiness for real-world application will be better supported.

5 Final remarks

Stroke remains one of the most serious medical conditions globally, requiring structured and continuous rehabilitation to support survivors in regaining lost functions and improving their quality of life. As every stroke survivor presents a unique combination of impairments, the rehabilitation process must account for these individual differences. Personalizing rehabilitation exercises is therefore essential to ensure that therapeutic interventions align with each person's physical, cognitive, and emotional needs.

Despite its importance, personalization in stroke rehabilitation has received limited attention, particularly from the perspective of healthcare professionals and stroke survivors who face the day-to-day challenges of implementing it. Personalizing therapy for each individual is a complex task, as it requires time, careful observation, adaptation, and ongoing monitoring, all of which can be resource-intensive and difficult to sustain in busy clinical environments. This highlights the need for a technological solution that can support and streamline the personalization process, making it more practical to apply consistently while also promoting ease of use and broader acceptance in real-world settings.

To begin addressing this challenge, our work proposes the use of Virtual Reality Serious Games as a platform for personalized stroke rehabilitation. As a first step, we conducted an online survey with healthcare professionals (key actors in the rehabilitation process) since they are the ones who oversee and adapt therapeutic strategies to each survivor. Their perspectives are essential to understanding what features should be personalized and how personalization can be implemented in clinical practice.

The results of the survey provided important insights into current practices, perceived challenges, and personalization opportunities in clinical settings. Regarding the modes of personalization, a strong preference emerged for a hybrid approach (70%), i.e., one that combines automatic system-driven adjustments with the possibility of manual intervention by healthcare professionals. Similarly, for the timing of personalization, the majority favored hybrid synchronization (50%), balancing real-time and post-session adaptations. In terms of relevant survivors data to support personalization, the most frequently cited was motivation (with 70%) followed by reaction to stimuli and emotional state (60%, each), highlighting the importance of tracking not just physical but also psychological states. Lastly, when considering functionalities in VR environments, professionals most valued the adaptability of the virtual setting and real-time feedback to guide confused survivors (both with 60%), along with dynamic task difficulty adjustment and adaptation to the survivor's clinical state (50% each).

We also discussed the limitations of the study, including the relatively small and localized sample, the absence of direct input from stroke survivors, and logistical constraints.

Moving forward, this work will prioritize expanding data collec-

tion to additional rehabilitation centers, with the aim of validating the current findings and capturing a broader range of perspectives. Including centers from different countries could also offer valuable insights into how cultural factors influence user expectations and personalization requirements. Building on the feedback collected, the next step involves co-designing a VR-based prototype in collaboration with healthcare professionals. This prototype will then be evaluated through targeted user studies. Finally, the research will extend to directly include stroke survivors, allowing for a more comprehensive assessment of the solution's impact on motivation, engagement, and the overall rehabilitation experience.

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