Supporting Stroke Rehabilitation Through Gamified Daily Activity Simulations

Lucas D. Barboza[1], **Franciely R. da Silva**[1],
Humberto G. de Oliveira[1], **Jullia C. de Oliveira**[1], **Antônio R. A. Brasil**[1]

[1] Centro Universitário Salesiano - Unisales
{lucas.barboza, anribrasil}@salesiano.br
francielysilva.31@hotmail.com
{humberto.garcia,julliacastro.oliveira}@gmailcom

Abstract. *This paper introduces the creation of an open-source virtual reality (VR) game for stroke rehabilitation by simulating daily activities. The game proposes immersive environments, including a tea room, bathroom, garden, and kitchen, designed to promote functional gesture movements and enhance user engagement by introducing gamification. Patients are rewarded with points for task completion, for example, grabbing a fruit and eating, thus creating a competitive and motivating environment. Preliminary testing with university students received positive responses, particularly regarding the realism of the tasks. However, extended use of VR resulted in reports of physical discomfort and headaches. Next steps include the approval for further testing by the Ethics Committee involving stroke patients.*

1. Introduction

Stroke continues to be a major global health concern, affecting millions of lives annually and posing a significant challenge to healthcare systems around the world [Li et al. 2024]. According to the World Health Organization (WHO), stroke is one of the primary causes of death and long-term disability worldwide, with approximately 13.7 million cases reported annually [Lindsay et al. 2019]. This underscores its widespread health impact across continents and demographics. Therefore, with prompt medical treatment and appropriate rehabilitation, it is possible to reduce disability, prevent sequelae, and enable individuals to come back to their activities [Powers et al. 2019].

Among the disabilities caused by a stroke in an individual, the conditions include sensory-motor deficits (such as dysphagia, facial paralysis, and visual impairments); limitations in daily living activities (difficulty with routine tasks like eating or personal hygiene); communication challenges (including aphasia and oral apraxia); cognitive deficits (such as dysfunctions in memory, calculation, and attention); and mood disorders (emotional disturbances) [Langhorne et al. 2011]. In this context, the difficulty in maintaining a seated position is classified as a sensory-motor deficit, which leads to a range of challenges for post-stroke patients. After a stroke, the ability to maintain seated balance while performing various tasks, both within and beyond arm's reach, is crucial for independent living. However, impairments in sitting balance are common among patients who have experienced a stroke [Lee et al. 2021].

After a stroke, the rehabilitation is crucial and involves multiple disciplines, including physiotherapy, occupational therapy, speech therapy, and psychological

[Langhorne et al. 2011]. With the aim of restoring damaged motor, cognitive, and communicative functions, early intervention is very important to help improve patients' quality of life and recover autonomy. Besides that, several challenges persist, such as the reliance on subjective evaluation by a healthcare professional, the difficulty in measuring clinical progress, particularly in areas like balance and coordination. Additionally, limited access to resources and unequal access to assistive technologies can affect the effectiveness of the rehabilitation, highlighting the need for innovative approaches [Lee et al. 2021, Powers et al. 2019].

In this context, non-immersive virtual reality training (VRT) involves the use of computational software that tracks users' movements and enables interaction with games or activities displayed on a screen. This approach offers a repeatable, convenient, and enjoyable experience for patient recovery after a stroke [Kang et al. 2023], with no restrictions on its usage [Thornton et al. 2005, Laver et al. 2017]. In general, games can improve rehabilitation or assist in physiotherapy [Mendes 2023, Larentis et al. 2024], and several studies have shown that VR games can be as effective—or even more effective—than traditional therapy [Gibbons et al. 2016, Darekar et al. 2015, Henderson et al. 2007]. Additionally, the simulation of daily activities using VR, such as virtual kitchens or basic reaching tasks designed for functional training, demonstrates various benefits in stroke rehabilitation [Laver et al. 2017, Cameirão et al. 2010]. However, as far as the authors are aware, there are no games specifically designed for stroke rehabilitation using daily routines; furthermore, no open-source games targeting these activities for rehabilitation have been found.

This work presents a serious game for stroke rehabilitation using virtual reality (VR) aiming to support the recovery process for patients affected by stroke. Our approach is based on the Guidelines for the Early Management of Patients with Acute Ischemic Stroke (GEMPAIS) [Powers et al. 2019], focusing on two specific interventions for individuals experiencing sitting difficulties: practicing the retrieval of objects placed far from arm's reach in all directions, and improving sitting posture to help proper body alignment.This proposal focuses on patients with mild to moderate motor impairment after stroke, particularly those with preserved cognitive function who are able to engage with immersive virtual environments. By creating a open-source VR game that incorporates four daily exercises (x, y, z, and w), this work aims to facilitate the rehabilitation process for stroke patients.

This paper is organized as follows: Section II presents related work, Section III describes the methodology, Section IV presents the tests and results, and, finally, Section V discusses the conclusion and future work.

2. Related Work

VR technologies for stroke rehabilitation have emerged as a relevant research area with significant growth in recent years, as reflected in advances in modern therapeutic approaches [Demeco et al. 2023, Hadjipanayi et al. 2024]. The pioneering study by Tsekleves et al. (2016) evaluated a non-immersive VR-based approach for upper limb stroke rehabilitation using the Wii system, with a single participant—a 31-year-old right-handed woman who had suffered a stroke 11 years earlier, resulting in left-sided hemiplegia. The results showed positive changes across the four outcome measures employed in the single-case

study, highlighting the intervention's fun and motivating aspects as well as the benefits of activity customization [Tsekleves et al. 2016].

Serious games and both immersive and non-immersive VR represent a promising frontier in occupational therapy and physiotherapy, helping engage patients and potentially improve treatment results. For example, Laver et al. (2017) proposed an immersive VR game that simulates challenging tasks, thereby engaging patients in repetitive, task-oriented exercises. Their analysis, which encompassed 72 trials with a total of 2,470 participants, concluded that when used alongside conventional therapy, VR can significantly improve upper limb function and activities of daily living—largely by increasing the overall time dedicated to therapy [Laver et al. 2017].

In another study, another game was created using an immersive VR environment aiming for upper limb rehabilitation post-stroke. By exploring a variety of scenarios designed to make the rehabilitation process both challenging and enjoyable, the authors created a virtual 3D system space in which patients could perform tasks closely resembling real-life movements. This approach also aimed to facilitate the transfer of motor skills acquired in VR to everyday routines. Conducted with 16 stroke patients who reported comfort using the immersive system, the study found that behavioral performance within the VR environment correlated with clinical scores on the Fugl-Meyer scale. These findings suggest that VR can serve as an effective tool for assessing and monitoring rehabilitation progress, although the authors emphasize that further research is necessary [Fregna et al. 2022].

Rocha et al. (2021) developed a non-immersive VR game called AVenCer for post-stroke rehabilitation in patients during the early stages of recovery. The game, which stimulates therapeutic movements—including shoulder flexion-extension, abduction-adduction, elbow flexion-extension, and wrist and finger movements—was tested on three patients with ischemic stroke. Two of the patients who participated in the therapy showed improvements in manual dexterity, execution time, and game scores. Although the results are preliminary due to the small sample size, the AVenCer system demonstrated a promising approach to enhancing manual dexterity and increasing patient engagement in the rehabilitation process [Rocha et al. 2021].

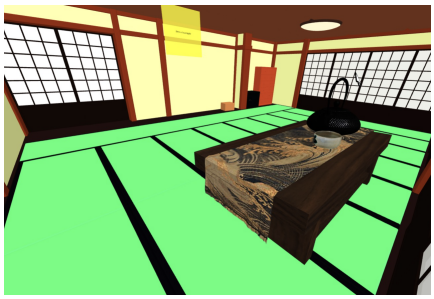
Castro et al. (2021) evaluated a VR game for upper limb rehabilitation in which users perform therapeutic hand movements—such as wrist pronation-supination, fist opening and closing, wrist flexion, and finger flexion—to defend against enemies in a fantasy environment. Tests conducted with seven participants resulted in suggestions for improvements in game mechanics, scenarios, motion detection, and clarity of instructions. Overall, the experience was positive, with an emphasis on the need for personalized adaptations and configuration options to better meet user needs, thereby contributing to enhanced therapeutic effectiveness and motivation [Castro Feitosa et al. 2022].

3. Neurophys - A Serious Game for Stroke Rehabilitation

Neurophys is a serious game composed of four environments, called levels, developed using Javascript language deployed on Glitch[1] and tested using Meta Quest 3[2]. These

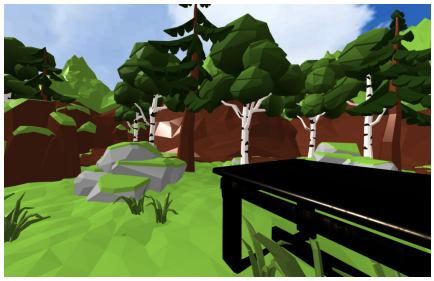
[1] glitch.com
[2] meta.com/quest

environments simulate daily activities to help the rehabilitation for daily routine. The proposal of this work consists in a development of a serious game for VR-based tasks using virtual reality glasses. Each user is prompted to write their name at the beginning. For each level, the user receives points when a task is completed, and the users can see the points of other users in a ranking. This was created to further engage users in completing each task. Figure 1 presents the levels created to simulate daily routines. Figure 1a simulates a tea room where the user can walk around, sit, and drink tea, and Figure 1b represents a bathroom. The task the user needs to do is to put toothpaste on the toothbrush, where the advice describing what the user needs to do is at the top of the screen. Figure 1c is a garden, and the task where the user needs to water the plant is by grabbing the watering can, and finally, Figure 1d is a kitchen and the task where the user needs to take each fruit and place it in their mouth.



(a) Tea room.

(b) Bathroom.



(c) Garden.

(d) KItchen.

Figura 1. VR environments.

4. Tests and Initial Results

The approach was tested with students from the Information Systems course at the Centro Universitário Salesiano - Unisales.The tests demonstrated student engagement with the point-based game and daily routine tasks, and these users reported a ”Realistic environment”which simulates real-life routines, validated by two physiotherapeutic professionals.

5. Conclusion

The work proposed a virtual reality game featuring real-life tasks for stroke rehabilitation. During the development and validation of the game, the authors observed high user engagement and noted the realistic environments created by students. However, one disadvantage identified was the physical discomfort caused by using the glasses for extended

Figura 2. Example of an user playing the game using MetaQuest.

periods, which led to headaches. The authors believe that incorporating a timer for each task in the environment could mitigate this problem. The next steps involve submitting the project to Plataforma Brasil for Ethical Committee approval to conduct tests with stroke patients, and a partnership with one of the leading hospitals in stroke care in the state of Espírito Santo is underway to validate the game.

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