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Can the Combination of Motion Tracking and Virtual Reality Make Shoulder Rehabilitation Entertaining?

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1. Introduction

Patients' adherence to the physiotherapeutic program is challenging, leading often to suboptimal recovery (Kern et al., 2019). Both virtual reality (VR) and gamification have the potential to increase patients' motivation and interest (Marley et al., 2022; Schuermans et al., 2022), shifting their focus of attention to the game instead of the challenging and potentially painful movements that they need to do for their rehabilitation, resulting in improved rehabilitation outcomes (Wulf et al., 2001).

Mostly due to their high prevalence, this study focused on the rehabilitation following three common shoulder treatments or pathologies: i) surgical stabilization of the glenohumeral joint following Latarjet's procedure (*Lat*), ii) frozen shoulders (*FS*), and iii) surgical repair of rotator cuff tears (*RCuff*). Each of these rehabilitations is usually subdivided into three phases. The first phase aims at preserving the patient's mobility while the injuries heal. The second phase aims to restore the articular range of motion (*ROM*). The third phase aims to restore the strength of the articulation.

The goal of this research project was to create a highly motivating and effective rehabilitation experience leveraging a set of high-quality VR games combined with commercially available VR hardware. This paper presents the pilot clinical study performed at La Tour Hospital, evaluating the feasibility, safety and user acceptance of the current games and physical setup on 15 patients.

2. Methods

Five *Lat*, five *FS* and five *RCuff* patients were tested (age: 39 ± 22 y.o.) targeting the timeframe between 2 to 5 weeks post-surgery, by undertaking 4 gamified sessions of 15 minutes each.

We used an HTC Vive Pro as VR headset combined with 2 hand controllers, and 5 Vive trackers 2.0 strapped to the patient's trunk, arms, and forearms to track the patients' upper body motions while immersing them in a custom-built relaxing VR environment developed in Unity. The accuracy of the tracking system for the VR hardware used was previously evaluated in Mancuso & Charbonnier, 2024.

The VR rehabilitation sessions consisted in solving several mazes that the patients controlled using the five or six main upper body exercises present in their rehabilitation protocol (Fig. 1). These movements allowed participants to tilt the virtual environment (pitch and roll) and adjust the elevation of certain platforms within the maze, thereby creating pathways that enabled a small mouse to navigate across it. The target motions of the affected upper limbs for *Lat* and *FS* patients were: i) pushing the shoulder forward, ii) pulling the shoulder backward, iii) pushing the shoulder upward, iv) flexing the elbow, v) wrist pronation, and vi) wrist supination. For the *RCuff* patients, the motions were: i) external rotation of the shoulder, ii) internal rotation of the shoulder, iii) flexion of the elbow, iv) extension of the elbow, v) anterior elevation of the arm. At the

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beginning of every session, the articular ROM of the patient was evaluated, and the exercises calibrated to match at least 80% of that range. Moreover, the mazes presented to the patients progressively evolved in complexity both to keep the patients' mind challenged and to increase the frequency of the movements needed to solve them.

Figure 1. User with the headset, and sensors strapped to his upper limbs and waist, solving a maze in VR using his shoulder's movements as input. On the screen in the background, a holographic coach stands ready to re-explain the motor tasks or to correct the user in case of erroneous movements. See also a demo video available at https://youtu.be/BAcPVS4HW40?si=3lIaqle9EZ224Umw.

After each session, the patients filled in a questionnaire aiming to measure the patient's i) cybersickness, ii) motivation (reduced version of the post-experimental Intrinsic Motivation Inventory (*IMI*), and iii) perceived risk during the tasks (3 custom questions). Moreover, the *IMI* questionnaire provided 4 scores to evaluate interest, competence, effort, and pressure. All the questions and subsequent scores were rated on a 1 to 7 scale, with 1 corresponding to "not at all true", 4 "somewhat true" and 7 "very true".

3. Results

All the patients involved were able to successfully complete the gamified protocol without particular difficulties. No patient reported significant amount of discomfort as confirmed by the Cybersickness scale (μ_{Lat}=1.2±0.5, μ_{FS}=1.5±1.1, μ_{RCuff}=1.1±0.3), with the main reported effect being "Ocular fatigue" (μ_{Lat}=1.7, μ_{FS}=2.1, μ_{RCuff}=1.0) and "Difficulty to focus" (μ_{Lat}=1.1, μ_{FS}=1.8, μ_{RCuff}=1.2). The patients did not feel endangered as confirmed by the evaluation of perceived risk (μ_{Lat}=1.0±0.2, μ_{FS}=1.4±1.0, μ_{RCuff}=1.2±0.6). Based on the subscales of the *IMI* questionnaire, the patients did not feel pressured (2.0±1.8), the effort perceived was average (4.2±2.1), but the interest (6.1±1.1) and perceived competence (5.3±1.3) were good.

4. Conclusions

This pilot study showed that patients were all able to perform the requested exercises while playing their rehabilitation games. Overall, within the limits of a small sample size of 60 sessions (15 patients performing 4 sessions each), the patients appeared motivated to perform their rehabilitation sessions without being exposed to risks or discomfort. Those results are promising, but a larger study involving a larger number of patients should be performed and compared with a control group to objectively and reliably measure the clinical validity and effectiveness of this VR approach. More specifically, we aim in a further study at i) validating the clinical effectiveness of the present approach both for the restoration of the patients' mobility and for the recovery of their capacity to perform their daily activities, and ii) extending the current methodology to other rehabilitation phases of the treatments presented.

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Conflict of Interest Statement

None.

Contributor Roles

MM: Data curation, Formal analysis, Investigation, Software, Writing – original draft; AL: Investigation, Supervision; YSD: Software; AS: Investigation; CC: Formal analysis, Supervision; All: Conceptualization, Methodology, Writing – review & editing.

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