Rehabilitation of Post-COVID Patients: A Virtual Reality Home-Based Intervention Including Cardio-Respiratory Fitness Training

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Abstract. The post-COVID syndrome is emerging as a new chronic condition, characterized by symptoms of breathlessness, fatigue, and decline of neurocognitive functions. Rehabilitation programs that include physical training seem to be beneficial to reduce such symptoms and improve patients' quality of life. Given this, and considering the limitations imposed by the pandemic on rehabilitation services, it emerged the need to integrate telerehabilitation programs into clinical practice. Some telerehabilitation solutions, also based on virtual reality (VR), are available in the market. Still, they mainly focus on rehabilitation of upper limbs, balance, and cognitive training, while exercises like cycling or walking are usually not considered. The presented work aims to fill this gap by integrating a VR application to provide cardio-respiratory fitness training to post-COVID patients in an existing telerehabilitation platform. The ARTEDIA application allows patients to perform a cycling exercise and a concurrent cognitive task. Patients can cycle in a virtual park while performing a "go/no-go" task by selecting only specific targets appearing along the way. The difficulty of the practice can be adjusted by the therapists, while the physiological response is continuously monitored through wearable sensors to ensure safety. The application has been integrated into the VRRS system by Khymeia. In the next months, a study to assess the feasibility

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of a complete telerehabilitation program based on physical and cognitive training will take place. Such a program will combine the existing VRRS exercises and the cardio-respiratory fitness exercise provided by the ARTEDIA application. Feasibility, acceptance, and usability will be assessed from both the patients' and the therapists' sides.

Keywords: Virtual reality · Post-COVID syndrome · Telerehabilitation · Physical exercise · Chronic diseases

1 Introduction

Italy has been severely affected by the SARS-CoV-2 pandemic, which resulted, in 2020, in a reduction of life expectancy by almost one year [1, 2]. COVID-19 spreading has also caused the interruption or the restriction of several clinical services that were not considered essential for the management of the emergency situation: among these, there were all the rehabilitation-related services [3].

Rehabilitation is crucial for chronic patients, as they need to exercise to avoid the further decline of their physical and cognitive abilities and to exclude the occurrence of secondary pathologies [4–6]. COVID-19 itself has contributed to increasing the number of chronic patients: 87% of people requiring hospitalization because of SARS-CoV-2 infection showed persistence of at least one symptom even at 60 days after discharge, even if tested negative at PCR [7]. Post-COVID (or long-COVID) symptoms entail fatigue, breathlessness, cough, pain, headache, joint pain, myalgia and weakness, insomnia, and neurocognitive issues, including memory and concentration problems [8, 9].

First evidence shows that rehabilitation in COVID-19 patients is effective in restoring pulmonary functions, reducing fatigue, and improving quality of life [10]. In particular, pulmonary rehabilitation usually addressed to patients with chronic respiratory diseases, turned out to be potentially beneficial in this new population of patients. Due to the variety of symptoms, rehabilitation in post-COVID patients must be customized and defined by a multidisciplinary team of specialists [11, 12].

Given this, the interruption of rehabilitation services during COVID-19 peaks has thus raised a question about how National Health Systems can invest in new strategies to support rehabilitation and continuity of care [13]. IT technologies may represent a quick and valuable solution, being flexible and available to most of the population worldwide (e.g., smartphones, tablets, and computers). Moreover, they allow administering treatments that are controllable also from remote locations, thus enabling the clinicians to monitor progress over time. IT technologies have also been tested in physical and cognitive rehabilitation programs and have been demonstrated to be well-accepted and motivate patients more than standard therapy [14].

Recently, several telerehabilitation systems have been made available on the market. These systems generally exploit a cloud-based architecture to enable data exchange between the patient and the clinicians and contain a series of exercises that the patient can perform at home. In addition, they often integrate different sensors that allow monitoring the physical activity and enable the generation of a performance report for the therapist. These systems have been validated in studies enrolling patients with mainly neurological, cardiological, and musculoskeletal diseases with positive outcomes [15]. However, most of them address cognitive issues, upper limb and trunk rehabilitation, and balance training. For reasons of safety, training programs aimed at retraining walking, strengthening lower limbs, or improving cardio-respiratory fitness are generally excluded. Nonetheless, the importance of endurance training (walking or cycling) is instead crucial for regaining autonomy in daily life for several groups of chronic patients, especially for post-COVID patients.

To fill this gap, this work presents a solution combining the current state-of-the-art with an innovative VR-based solution allowing for the training of lower limbs and aerobic capacity in a safe way. In detail, we designed and developed a system integrating a cycle-ergometer and a virtual environment allowing for the combined training of physical and cognitive abilities. The use of the cycle-ergometer excludes the risk of tripping and falling that could instead be present when using other devices like treadmills and force boards. Moreover, previous studies have demonstrated this device to be safe even in the case of frail older adults [16].

Such an application has been integrated into a commercial telerehabilitation platform, namely Virtual Reality Rehabilitation System (VRRS) by Khymeia, already including exercises dedicated to cognitive abilities, upper limb, and respiratory functions. In such a way, we obtained several advantages: (i) clinicians will have the chance to adapt the training program according to each specific patients' needs – also including an aerobic and lower limb exercise; (ii) patients can train at home, avoiding the risk of a (re)infection, and more continuously; (iii) patients can be monitored by the therapists, who can also revise the training program.

The remainder of this paper is structured as follow: Sect. 2 presents related works; Sect. 3 presents the rationale and the architecture of the application, together with the devices needed for its functioning; Sect. 4 presents the protocol we design to assess the feasibility of an intervention combining VRRS cognitive and upper limb-dedicated exercises and our virtual environment; Sect. 5 outlines future works and draws the conclusions.

2 Related Work

In recent years, several telerehabilitation platforms, also including VR scenarios, have been presented both in the literature and on the market. In our project, we focused on commercial solutions, already certified as medical devices, that guarantee a high degree of robustness and security, needed to ensure patients' safety and privacy. A first example is represented by MindMotion GO and MindMotion PRO, developed by Mindmaze[1]. These two telehealth solutions, CE-certified and FDA-approved, are designed for patients with mild/moderate to severe neurological diseases. Thanks to the integration with motion tracking devices (Microsoft Kinect and Leap Motion), they allow performing neurorehabilitation exercises for the upper and lower body in the form of serious games. The patients who tried the solutions at home showed clinical outcomes comparable with the standard treatment and a higher awareness of their capabilities. Another

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[1] Digital therapies for neurorehabilitation: MindMotion, available at: https://mindmaze.com/healthcare/mindmotion.

example is the BTS Telerehab[2], a medical platform by BTS Bioengineering, based on a wearable sensor that can be placed on different body districts and allows performing both motor/cognitive rehabilitation exercises and functional evaluation tests connecting to a digital application. The application shows the video image of the patient and overlaps some graphical elements that guide him/her towards a correct execution. It also allows the therapist to connect remotely and access a detailed report on the patient's progress.

A third example is RIABLO[3] system by CoRehab, a medical device composed of wearable sensors and a stabilometric platform that can be adapted to different users, including orthopedic and neurologic patients and individuals with spinal injuries. The system includes a library of serious games for balance training, upper and lower limbs rehabilitation, back pain, and total joints rehabilitation. Finally, the VRRS system[4] by Khymeia, which will be further described in the following section, is a medical device certified Class I, that provides comprehensive rehabilitation and telerehabilitation based on virtual reality.

All of these commercial solutions undergo clinical trials to test their efficacy with different groups of patients, mainly with neurologic, cardiac, orthopedic, and muscle-skeletal disorders. The results of these studies are promising in terms of acceptability, feasibility, and cost-effectiveness and show that telerehabilitation programs are comparable to the standard ones. However, even if some important steps have been done with respect to the past, there is still a need for well-structured procedures to integrate them into the clinical practice.

From the early stages of the COVID-19 pandemic, clinical experts have suggested that exercise may be beneficial for the most frequent clinical manifestations of post-COVID syndrome. Pulmonary rehabilitation protocols, specifically, can be personalized for post-COVID-19 patients, given the similarities in terms of symptoms and possible pathogenic mechanisms with patients with chronic respiratory diseases [17, 18]. The World Health Organization (WHO) stated that both aerobic and strengthening exercises might help patients in increasing fitness, muscle strength, balance, and coordination, reducing breathlessness, and improving confidence and mood. Exercise intensity should be adequate for the specific patient and, therefore, should be carefully defined based on clinical evaluations [19]. Although the scientific evidence is still limited, the literature presents some studies and case reports confirming such assumptions. One of the first studies showed how a structured exercise intervention improved physical function in a group of 33 post-COVID elderly patients. The intervention consisted of 30-min daily multicomponent therapy, including upper and lower limb resistance exercises, endurance training (step, cycle ergometer, or walking), balance exercises, and breathing therapy [20]. Another study presented four cases with different degrees of severity, showing that a physical exercise program based on cardiovascular and pulmonary rehabilitation improved functional capacity in all patients, disregarding the severity of their health

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[2] BTS Telerehab – Telerehabilitation – Rehabilitation at home as in the clinic, available at: https://www.btstelerehab.com/teleriabilitazione/.

[3] RIABLO – Motivate your patients, measure the movement, available at: https://www.corehab.it/en/riablo-bf/.

[4] Khymeia VRRS – Virtual Reality Rehabilitation System, available at: http://khymeia.com/en/products/vrrs/.

condition [21]. Exercise may be relevant not only to recover physical function but also for cognitive and psychological aspects. Recent findings indicate that post-COVID are, indeed, more likely to manifest cognitive impairment 12 or more weeks after the diagnosis [22]. Despite still-limited evidence, the effects seem more significant in attention and executive functions domains [23]. Therefore, including neuropsychological treatment in post-COVID rehabilitation seems relevant for patients' recovery.

Given its relevance, several clinical and scientific communities have already made several efforts to propose engaging and effective training based on cycling. Augmenting cycling with VR has proven feasible and effective in improving patients' motivation, also acting as a distraction from the perceived physical effort [24–26]. Both aspects contribute to improving exercise tolerance and, consequently, the treatment compliance that, especially for chronic patients, is often a critical issue.

Past experiences of our research group, CNR-STIIMA, demonstrate how training on an ergometer with a VR system simulating a ride in a park is a feasible and promising solution for different groups of patients. The first example is a VR-based intervention, including physical training on the cycle-ergometer and cognitive training in a virtual supermarket. The intervention, tested in a group of older adults with Mild Cognitive Impairment, resulted effective in reducing some physiological markers of neural decline and was largely accepted by all the participants in the intervention groups, who reported to have enjoyed this innovative training program and to feel better after its conclusion [27]. A more immersive version, based on a CAVE and integrating a cognitive task, was proposed to a group of frail elderly to assess its usability; such an experience demonstrated acceptable, involving, and free from any side effects [16]. Another study presented an adaptation of the virtual park for endurance training in pulmonary rehabilitation. The usability and acceptability of the system were tested on 8 patients with respiratory diseases, who found the VR motivating and a positive distraction from the feelings of fatigue and breathlessness caused by the exercise [28]. Our system can be interfaced with different VR devices (e.g., HMD, projected screen, CAVE), integrates various sensors (e.g., heart rate bands and pulse-oximeters), and implements different training protocols. These features are adapted depending on the context of use and the target users, thus allowing a high degree of personalization. This modularity opens the possibility to provide a useful tool also for patients recovering from COVID-19.

3 ARTEDIA Application

The application developed within the presented project, namely ARTEDIA, consists of a virtual reality (VR) environment supporting aerobic/lower limb training. Such an application has been integrated in the Khymeia platform to make it available for patients using their VRRS system.

Given the potential offered by the VR technology, we also added a cognitive exercise to perform concurrently. The rationale of this choice is two-fold: (i) to train post-COVID patients' cognitive abilities, which may also be impaired; (ii) to distract – at least partially – the persons from the physical effort they are doing by providing them with an engaging task shifting the attention away from the physical sensations [24, 29]. The application presented in this work is integrated into the VRRS system by Khymeia to allow the delivery of a complete telerehabilitation intervention.

3.1 Equipment

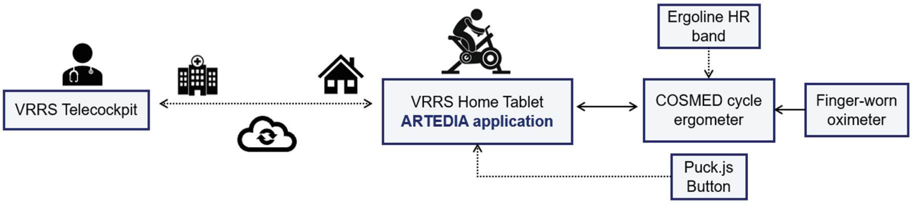

Fig. 1. Diagram of the ARTEDIA system integrated in the VRRS platform.

The equipment of ARTEDIA project comprises a VR-based system for cycling training and the VRRS telerehabilitation system. A diagram of the whole system is represented in Fig. 1.

The VRRS system, developed by Khymeia, offers different rehabilitation modules, each providing specific functionality, e.g., cognitive, speech therapy, neuromotor, respiratory, orthopedic exercises, both in the form of serious games and with a virtual assistant. Some studies demonstrated how rehabilitation with VRRS is equivalent to the standard intervention on different groups of patients, e.g., people with brain injury or patients with aphasia [30, 31]. The system's modularity allows the use in the clinic and at home.

In the case of telerehabilitation, the system is composed of the Telecockpit and the VRRS Home Tablet. The first is a desktop application installed at the hospital that allows the therapist to configure the rehabilitation plan for the specific patient by setting specific parameters for each exercise, e.g., the duration, the number of repetitions, the level of difficulty, etc. It also allows controlling patients' performance remotely, both directly interacting with them and visualizing the report generated by the platform. The VRRS Home Tablet is a Windows-based tablet (i.e., Microsoft Surface laptop) through which the patient follows the prescribed rehabilitation plan. Thanks to the integration with one or more external devices, the patient receives real-time feedback and directly interacts with the virtual contents. The communication between the Telecockpit and the Home Tablet occurs via a web cloud platform.

The main components of the VR cycling system, which has been integrated into the VRRS, are a cycle-ergometer, a button for the execution of the cognitive task, and one or more wearable sensors for measuring the physiological response.

The ergometer is a certified medical device by COSMED[5], which is connected through a serial cable to our application. The ergometer receives signals from two wearable devices: an Ergoline chest band to measure heart rate (HR) and a finger pulse oximeter to detect oxygen saturation level (SpO_2). The latter is required for those patients who suffer from respiratory deficits to control exercise-induced desaturation. The data exchange between the ergometer and the VR environment is handled within Unity

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[5] COSMED ergometers, available at: https://www.cosmed.com/it/prodotti/ergometri/cicloergometri-cosmed.

through an ad-hoc communication protocol that allows retrieving the cycling speed, the HR, and the SpO_2 and controlling the workload to adjust the exercise intensity.

The ergometer is connected via cable to a USB port of the tablet. A Puck.js button[6] communicates via Bluetooth with the ARTEDIA application through a library provided by Khymeia. To ensure patient safety and ease the interaction with the button and the VR environment, ad-hoc support has been 3D-printed.

The VR environment application, presented in Sect. 3.2, has been installed on the Home Tablet to be retrievable when launched from the VRSS system.

3.2 Exercise

As mentioned, the VR environment is designed to support both physical and cognitive tasks. It has been developed with Unity exploiting existing assets (i.e., Gaia[7], Curvy Spline[8]) and integrating the functionalities to make it available in the VRRS Khymeia platform.

The environment represents a park in which the patient travels while cycling; the forward velocity in the VR environment is synchronized according to cycle-ergometer currently-measured RPMs. The path to follow in the park is predefined and has been designed placing nodes along the path, which are subsequently interpolated with a spline.

The implemented cognitive exercise foresees the accomplishment of a "go/no-go" task, meaning that the patient has to react when a "go" target appears and do nothing when a "no-go" target does. In our application, go targets are represented by monsters, while no-go targets are animals; both are randomly instanced at runtime on either side of the path. During the exercise, patients have to press the button each time a monster appears alongside their path. To handle the selection of targets, we implemented a trigger collider (i.e., an object able to detect collisions but with no physical properties) that moves along with the virtual bike. Targets are selectable only if they are within the volume of such an object. Each time the patient presses the button, the target disappears, and visual feedback is provided showing if the reaction was due or not (Fig. 2). In case of a missed target, no feedback is provided.

To allow the therapists to customize the task according to the patients' needs, different parameters can be configured within ARTEDIA application; these are:

- Level of difficulty of the cognitive exercise (1–2–3): by adjusting this value, therapists could set how frequently the target is generated and if and how it is highlighted (Fig. 3). In level 1, targets appear every 15 s, go targets are highlighted in red, and no-go targets in green; in level 2, targets appear every 12 s and are all highlighted in the same way; in level 3, targets are generated every 10 s, and no highlight is provided.

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[6] Puck.js - the JavaScript Bluetooth Beacon, available at: https://www.puck-js.com/.

[7] Gaia Pro 2021 - Terrain & Scene Generator by Procedural Worlds, available at: https://assetstore.unity.com/packages/tools/terrain/gaia-pro-2021-terrain-scene-generator-193476.

[8] Curvy Spline by ToolBuddy, available at: https://assetstore.unity.com/packages/tools/utilities/curvy-splines-8-212532.

Fig. 2. Feedback for the wrong and the correct answers.

Fig. 3. Go target, level 1 (left); go target, level 2 (center); no-go target, level 3 (right).

- Cycle-ergometer workload (30–40–50–60–70 W);
- Maximum heart rate (HR): this represents a safety threshold; if the measured HR overcomes and stays over this value for 10 s, the exercise is automatically interrupted.
- Minimum oxygen saturation (SpO_2): this represents a safety threshold; if the measured SpO_2 decreases and stays below this value for 10 s, the exercise is automatically interrupted.
- Exercise duration (10–15–20 min).

The velocity to keep during the exercise is fixed and in between 60 and 70 RPM.

A graphical user interface (GUI) is displayed during the exercise to show the patients all the relevant exercise-related variables. Given the context of use, i.e., at home with no supervision of the clinical personnel, this is an important feature to ensure the patients and their caregivers are always aware of the situation and physiological parameters, in particular. The GUI is also used to communicate errors of different types, such as: (i) cycle-ergometer absence or incorrect setup resulting in an impossible communication with the environment; (ii) lack of signals from the HR and/or the SpO_2 sensors; (iii) too low velocity during the exercise. To be clear and avoid misunderstandings, all these error messages are given via written text (Fig. 4).

Velocità troppo bassa!
La velocità target è tra 60 e 70 RPM

Fig. 4. A screenshot of the ARTEDIA environment. At the top of the screen, written text signals that the current velocity is too slow. Other indicators report (from the top to the bottom): HR and SpO2 values, RPMs, remaining time, and number of correctly-selected targets.

All the configuration parameters are made available to the therapists via the VRRS Khymeia dashboard running on the Telecockpit and are subsequently configured in the ARTEDIA application each time a patient launches it on his/her Home Tablet. Therapists have also access to the performance data that are stored during the course of the exercise. These are correct answers (selected go targets, not selected no-go targets), errors (not selected go target, selected no-go targets), average speed, average HR, and SpO_2.

4 Feasibility Study

Given the innovativeness of the proposed intervention, we designed a study to evaluate its feasibility both for patients and for the clinical personnel. In fact, as mentioned before, this approach could positively impact on QoL of patients, who can benefit from continuity of care, and also on therapists who can provide assistance to more patients at the same time.

Indeed, the study aims to assess these two aspects rather than the clinical effectiveness of the intervention. About the study outcomes, we expect that if patients perceive the system as meaningful and usable, their attitude toward new technologies and their willingness to use the system in daily life will improve. The same is worthy for the clinical personnel, who need to comprehend and acquire confidence with the paradigm of home-based rehabilitation prior to implementing it in the standard practice. To verify whether the latter results are generalizable to different contexts, the study we designed is multicentric and foresees the participation of three clinics in Lombardy: (i) Ospedale Valduce, Clinica di Riabilitazione Villa Beretta, (ii) IRRCS E. Medea – La Nostra Famiglia, and (iii) IRCCS INRCA. The study protocol has obtained clearance by the medical ethical committees of the three involved centers.

4.1 Participants

The feasibility of the rehabilitation intervention will be carried out involving a number of patients between 30 and 35 enrolled among the patients of the involved clinics. Sample size calculation was made considering the Attitude toward Technology Questionnaire developed Huygelier et al. [32] as the main outcome (effect size: 0.69, $\alpha = 0.05$, power $= 0.9$).

The high degree of personalization of the treatment, the continuous monitoring of the patient with the possibility of changes in the rehabilitation protocol, and the opportunity to perform the training at home allowed proposing this telerehabilitation program not only to post-COVID patients but also to other populations of users who may benefit from a home-based program including lower limb and cardio-respiratory training. For example, further users can be: patients with respiratory diseases in which aerobic and muscular exercises are strongly recommended [33], post-stroke patients who need to train the lower limbs and perform cognitive training [34], and young people with neuromotor pathologies for which pedaling can have beneficial effects [35, 36].

Thus, we will include patients over 12 years old who have respiratory issues due to COVID-19 or other pathologies (e.g., COPD), or with either congenital or acquired neuromuscular disorders, and who may benefit – according to their therapist – from a multidisciplinary home-based motor and cognitive intervention. All the enrolled patients have to be settled in the Lombardy region and have at least one caregiver who can provide informal assistance during the home-rehabilitation period. Moreover, all participants or their legal tutors (in case of underage) have to sign an informed consent form.

Exclusion criteria will be: chronic pain, tracheostomy or need of oxygen therapy for more than 18 h a day, severe cognitive, sensory, or motor impairment preventing the person from making use of the provided equipment and/or performing a moderate physical effort; severe communication deficits, dysmetria, renal insufficiency, or hepatic insufficiency; history of epilepsy and contraindication of their therapist.

4.2 Protocol

The telerehabilitation program is made the following phases:

1. **Undertaking the patient.** The telerehabilitation program is offered to patients who meet the inclusion criteria described above and their caregivers during the hospitalization or at its end. Patients sign the informed consent.
2. **The Individual Rehabilitation Program (PRI) is defined**. A personalized training program is proposed after the evaluation of the patient's baseline through ad-hoc clinical scales. The program could include both functional-motor and cognitive exercises available on the Khymeia platform (including ARTEDIA application) such as:

(i) upper or lower limb motor control; (ii) trunk stability and balance, (iii) speech therapy; (iv). training attention and memory.

3. **Patient and caregiver training.** The patient and his/her care-given are invited to the clinic of reference to be informed about the system functionalities. A training session with the VRSS laptop and the cycle-ergometer is performed under the supervision of a therapist. Also, documentation about the telerehabilitation program is provided to users.
4. **Delivery of technological equipment.** The cycle-ergometer is installed at home and the correct functioning of the system is verified.
5. **Execution of the rehabilitation program and monitoring.** The patient is monitored remotely, thus allowing clinicians to manage and eventually modify the exercises. The intervention program lasts 4 weeks: users will exercise 5 days a week for 1 h; training can be divided into 2 sessions of 30 min, both to facilitate compliance and adapt to the patient's lifestyle while maintaining the overall intensity of the treatment. Each session will include a set of – cognitive and/or motor – exercises tailored to the needs of each patient.

   A teleconsultation session is scheduled every 8 days with the therapist in charge of the patient's treatment to review his progress and check the performance of exercises; in this way, the therapist could redefine the rehabilitation program if necessary.
6. **Results.** A personal report is created using measurements obtained during the entire duration of the treatment.
7. **Analysis.** Data collected from patients and from the therapists involved in the study are analyzed to identify the strengths and weaknesses of the approach and to design guidelines for future telerehabilitation interventions.

4.3 Measures

As mentioned, the main study outcome is the attitude towards technology and how it will change in the users who will use the telerehabilitation program. For this purpose, users will be asked to fill in the Attitude Questionnaire before and after the intervention (Huygelier et al. 2019).

Some scales will be proposed at the baseline to evaluate if the participants suit the defined inclusion criteria; these are: (i) Visual Analogue Scale for Pain - VAS Pain [37]; (ii) Trunk Control Test [38], to assess trunk stability; and (iii) Mini Mental State Examination [39] to evaluate cognitive function. For patients with respiratory issues, a simple spirometry test will be performed, and the following scales will be administered: (iv) Dyspnea scale (Modified British Medical Research Council questionnaire, mMRC [40]); (v) 6-min walk test (6MWT) [41]; (vi) Short Physical Performance Battery (SPPB) [42]. Lower limb functions will be assessed with sensorized pedals allowing to retrieve the work produced by the two legs, mechanical effectiveness and symmetry indexes [43].

At the end of the training program, in addition to the Attitude Questionnaire, the following outcomes will also be assessed for each patient: (i) the overall workload necessary to complete the rehabilitation program, with NASA Task Load Index (NASA-TLX, [44]), (ii) the usability of the system, with System Usability Scale (SUS, [45]) and (iii) the acceptance of the technological system using a questionnaire based on the Technological Acceptance Model [46].

Finally, after the six months dedicated to the study execution, a semi-structured interview will be proposed to therapists who assisted the patients throughout the telerehabilitation program to evaluate usability, acceptance, and personal opinion about this technical proposal.

5 Conclusions and Future Work

This work presents a virtual reality-based application developed to support physical and cognitive rehabilitation in chronic patients. In particular, the ARTEDIA application has been integrated into an existing telerehabilitation platform to allow the delivery of a customized training program at home. Though it has been conceived to treat post-COVID patients, its use can be extended to other patients who can benefit from continuity of care.

We also present the feasibility study we designed to assess the feasibility of such an intervention, which will foresee the creation of a customized training program including both our applications and the one that Khymeia already provided within their platform (i.e., application for cognitive, upper limb, and respiratory training).

In the next months, the study will start with the enrolment of the patients in the three clinics. If the study has a positive impact both for patients and their therapists, larger trials are recommended to better assess the clinical effectiveness of the proposed interventions. These trials will also pave the way to define a roadmap for the implementation of home-based rehabilitation as part of the standard care recognized by the Regional and the National Health systems.

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