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Personalized Virtual Reality Environments for Intervention with People with Disability

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Abstract: Background: Virtual reality (VR) is a technological resource that allows the generation of an environment of great realism while achieving user immersion. The purpose of this project is to use VR as a complementary tool in the rehabilitation process of people with physical and cognitive disabilities. An approach based on performing activities of daily living is proposed. Methods: Through joint work between health and IT professionals, the VR scenarios and skills to be trained are defined. We organized discussion groups in which health professionals and users with spinal injury, stroke, or cognitive impairment participated. A testing phase was carried out, followed by a qualitative perspective. As materials, Unity was used as a development platform, HTC VIVE as a VR system, and Leap Motion as a hand tracking device and as a means of interacting with the scenarios. Results: A VR application was developed, consisting of four scenarios that allow for practicing different activities of daily living. Three scenarios are focused on hand mobility rehabilitation, while the remaining scenario is intended to work on a cognitive skill related to the identification of elements to perform a task. Conclusions: Performing activities of daily living using VR environments provides an enjoyable, motivating, and safe means of rehabilitation in the daily living process of people with disabilities and is a valuable source of information for healthcare professionals to assess a patient's evolution.

Keywords: immersive environment; cognitive impairment; physical disability; unity; rehabilitation

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1. Introduction

During the rehabilitation process of people with disabilities carried out in therapeutic centers, appropriate work environments are generally reproduced in order to improve different physical and cognitive skills. Activities of daily living are frequently practiced in these sessions to increase the patient's functional capacity as well as consequently his or her independence. The configuration of an appropriate workspace to practice such activities can become very complex. This may give rise to physical or economic barriers that hinder access to such environments by healthcare institutions and entities.

Thus, in order to practice different household tasks such as cooking, setting the table, doing the laundry, or gardening, it may be necessary to have certain rooms in a house as well as the necessary equipment. In addition to household chores, other examples of daily activities that are often the subject of therapeutic intervention include shopping in a supermarket, driving a car, moving around a city independently, and activities related to personal care.

It is unfeasible for a healthcare center to have effective environments for the development of all of the above activities. In addition, the execution of certain activities in real spaces without adequate training may pose a risk to the user and his or her environment, including such activities as driving vehicles, handling certain household products, and using kitchen utensils.

As a solution to the previous problem, the use of virtual reality (VR) has been proposed to generate virtual spaces for the practice of daily life activities. VR is a technological resource that allows the generation of environments with a real appearance and interaction with the different elements of scenarios in a similar way as would happen in the real world [1].

The use of virtual environments represents an interesting possibility to reduce the physical and economic limitations in existing configurations, and can generate a safe way of working with those tasks that can represent a danger for the user until he or she has the appropriate skills. In addition, the use of VR can offer better results in certain exercises compared to conventional rehabilitation. This has been pointed out in a study carried out with people with Parkinson's in which the use of VR and conventional rehabilitation was compared [2].

In that case, a VR application was created consisting of four scenarios = representing activities of daily life configured in such a way as to train various physical and cognitive abilities. Three of the scenarios aimed at improving the grip and manipulation of items with the hands and practicing wrist movement. The remaining scenario was intended for practicing the identification of items in the performance of an everyday task.

Unlike other studies [3–5], games or commercial applications of general scope have not been used. These are personalized environments adapted to people who require training for some physical or cognitive pathology. Other noteworthy cases include the use of the Leap Motion device, which allows users to interact with their hands in VR scenarios without the need for controls.

2. Related Work

After a bibliographic analysis of the use of VR equipment in intervention processes for people with disabilities, several studies with satisfactory results stand out and invite further research along these lines. An example of this is a case study on elderly people, including two people with Parkinson's disease [6]. In this study, two tests were performed in virtual environments: a purely observational test used as the first contact with VR, and another that involved the movement of different parts of the body and coordination movements. As equipment, the authors used HTC VIVE VR glasses, two controllers, and sensors to delimit the workspace, and used TheBlue [7] and NVIDIA VR FunHouse [8] games on the software side. TheBlue is a relaxing and mainly observational experience, and was used to introduce users to VR technology. At the end of its run, users were asked about the presence of cybersickness. In the NVIDIA VR FunHouse game, the participants had to perform different tasks such as picking up and throwing objects or popping balloons. Through these tasks, they worked on body movement and coordination. As a result, the authors noted that all participants completed the tests successfully and without adverse effects. In addition, they pointed out that one of the participants used a wheelchair and that because of his pathology he had dorsal kyphosis (curvature of the spine in the cervical area), which made it difficult for him to fully visualize the virtual environment. In order to solve this problem, they tilted his chair during the activity. All users were satisfied with the tests and were willing to repeat them, even recommending their use. As for improvement, one of the participants mentioned possible improvements to the ergonomics of the controls, and one of the users reported slight fatigue at the end of the second test as well as an increase in saliva.

Several studies about the use of VR in the rehabilitation of people following strokes have considered this technology a promising technique in the rehabilitation process [9,10]. As concerns our proposal, we find very interesting the work carried out by researchers at the Polytechnic University of Barcelona in collaboration with the Functional Diversity Association of Osona (ADFO) [11]. In this study, two VR applications were developed oriented to the treatment of physical and cognitive disabilities, mainly aimed at people who had suffered a stroke. The physical rehabilitation application consisted of an avatar to guide the user in the movement of different parts of the body. The cognitive rehabilitation application uses an environment that simulates a supermarket, in which the user has to do their shopping. The objective is to improve memory, coordination, and attention. The hardware used once again consists of HTC VIVE VR glasses, two controllers, and sensors that delimit the workspace. On the software side, it is worth noting that the VR scenarios were developed by the project's researchers. This allowed them to customize the work environments and direct them to the treatment of a series of specific physical and cognitive abilities, a very positive and differentiating aspect compared to other studies.

It is necessary to mention the WalkinVR application [12], which aims to make VR accessible to people with disabilities. This tool can adapt any game or VR environment from the Steam VR catalog. In addition, it is compatible with multiple VR devices, such as HTC VIVE and Oculus Rift. Its main functions are:

- Virtual Movement and Rotation, a function aimed at users with mobility problems, such as those who use wheelchairs or are bedridden;
- Assisted Play, a function designed for people with mobility disorders that make it difficult to use controllers to move around in a game;
- Controller Position Adjustment, which allows solving certain movement restrictions, such as having to place the game controllers at a certain height;
- Hand Tracking. a function aimed at people who, due to their pathology, cannot hold game controllers.

Despite not being a tool aimed at the rehabilitation of people with disabilities, this is a very interesting option in many ways, as it facilitates access to VR for people with certain physical or cognitive conditions. In addition, various games can be used for the rehabilitation of certain pathologies, which provides a safe, enjoyable, and motivating medium for intervention sessions for people with disabilities. However, by using commercial games there is no customization of activities to the pathologies of the users, something that is considered in our proposal.

In summary, the studies analyzed above suggest that VR can be a very interesting tool in rehabilitation sessions for people with disabilities. The use of VR environments is an enjoyable, motivating, and safe way to perform physical or cognitive exercises. Our proposal is not limited to the rehabilitation of physical or cognitive skills; rather, it has exercises for working on both types of skills. Particularly noteworthy is the customization of scenarios and the use of the hands as a means of interaction, which eliminates the need for controls. The non-use of controls is noteworthy because it significantly increases immersion in VR environments and provides greater realism in the performance of activities. In addition, in the context of rehabilitation it is even more important, as some users with physical pathologies involving their hands may have difficulties in holding and handling controllers. Interaction through the hands for a long time can be more fatiguing than other means of interaction [13]. Another differentiating aspect of our proposal is the special care involved in the design of virtual environments. Numerous 3D models were configured in order to be as close to reality as possible. Likewise, deep work was performed in the development and implementation of the functions in order to achieve a realistic interaction with the objects of the scene. As a result, great immersion of the user in the VR scenarios was achieved along with an interaction system that allows movements very close to reality.

Although VR has been presented as a promising technology in the rehabilitation process of people with disabilities, there are limitations to be aware of. The use of VR scenarios by blind or deaf people can offer certain barriers without adequate help. However, there are studies that deal with this problem and that provide hopeful results [14,15]. In addition, an interesting study [16] reflects the importance of analyzing factors that influence the perceived stigma associated with the use of assistive technologies. Greater care in development could reduce technology abandonment and perceived stigmas. Possible difficulties in implementing VR systems in rehabilitation centers should be taken into account. Healthcare professionals do not usually have close contact with ICTs, and care must be taken in designing applications in order to make them simple and intuitive.

3. Materials and Methods

Meetings were scheduled with different entities and organizations in the health field, particularly those working with people with disabilities. The objective of these meetings was to obtain information about the work sessions implemented by professionals for the users of these centers. Different needs and improvements in the therapeutic sessions that could be solved through the use of VR scenarios were registered. Thus, the pathologies to be treated, the virtual scenarios, and the actions that users should perform in these environments were defined. Four scenarios were agreed upon: the first scenario represented a living room and was intended to train movement with the hands (displacement, grip, and rotation). Users had to place different pieces of fruit in a fruit bowl, which involves practicing different grip modes. The second scenario simulated a kitchen, and aimed to improve difficulties with wrist movement. Users had to turn on a faucet, fill a jug with water, and turn the faucet off again. The third scenario again represented a living room; its purpose was to train the handling of cutlery. Users had to hold a fork and knife and cut a piece of meat. The fourth scenario represented a kitchen, and its objective was to practice the identification of elements required to carry out a task. Users had to select the foods needed to prepare breakfast and the appropriate cutlery to eat it.

Once the scenarios were defined, the appropriate components for the development of the application were selected and configured. Unity was used as the development platform for the VR scenarios, in combination with different plugins and libraries. To generate the VR experience, HTC VIVE glasses and a Leap Motion device were used. Sections 3.1 and 3.2 describe in detail the software and hardware used.

After the development of the application, three discussion groups were organized with the centers of people with disabilities. Four users and four health professionals participated in each session. All participants had a spinal injury, stroke, or cognitive impairment. Each user tried only those VR environments suitable for their pathology. The tests were developed in the controlled environment of the research group's lab. A qualitative perspective was followed in which the perceptions and opinions of users and health professionals were recorded. In order to do this, several questions were defined:

- How people felt about the use of VR equipment and scenarios;
- Whether VR environments were considered useful in the rehabilitation process;
- What components would participants remove;
- What elements could be incorporated into the design of the scenarios;
- How the users felt during and after finishing the activity.

3.1. Hardware

- HTC VIVE is VR equipment created by HTC and Valve [17]. It performs the visual representation of VR applications and allows the user to interact with the scenarios. The main components of this equipment are glasses, controls, and position sensors.

Additionally, it is necessary to have computer equipment that meets the minimum requirements specified by the manufacturer and to prepare the physical space where the users will move. An area of a minimum of 3 m^2 and a maximum of 15 m^2 is required for the position sensors to be placed. After all of the components have been installed, we simply need to run a game on the computer, put on the glasses, grab the controls and step into the play area.

- Leap Motion: This is an optical system capable of tracking the hands and fingers, allowing interaction with digital content such as games or applications of different kinds [18]. This device integrates perfectly with the HTC VIVE glasses (Figure 1). Considering the objectives of this project, the use of Leap Motion provides great benefits in the interaction with the elements of the different scenarios. In addition to providing much more realistic environments, the amount of movements that can be performed with the hands is not comparable to that which a remote control allows.

For these reasons, it was decided to make use of this device in all of the scenarios we developed.

Figure 1. HTC VIVE glasses with Leap Motion.

3.2. Software

- Unity [19]: This is a real-time 3D development platform which allows the creation of interactive environments for multiple platforms, including PC, consoles, or VR equipment [20]. It is available with Windows, Mac OS, or GNU/Linux operating systems and offers various types of licenses classified according to whether it is to be used in a personal or business environment.
- OpenVR [21]: This is an API created by Valve that allows access to the hardware of different VR equipment such as HTC VIVE or Oculus Rift. It is necessary to add OpenVR in Unity to correctly compile the environment and obtain a functional program for the HTC VIVE device.
- SteamVR [22]: This runtime environment allows the use of applications developed with the OpenVR API.
- Unity Leap Motion Modules: The manufacturer of Leap Motion provides various modules [23] that must be imported into Unity to access the API of the device, as well as different resources that will facilitate the development of the different scenarios. Specifically, in this project, the Core and Interaction Engine modules were used.

4. VR Application

The solution proposed in this project consists of a VR application that has different environments simulating situations of daily life, configured in such a way as to allow training of various physical and cognitive abilities. The use of spaces that represent situations of real life is intended to allow the user to train that physical and cognitive problem naturally through action or challenge that he/she is likely to have to perform daily.

As the usual Unity programming methodology was followed, first, the different 3D objects that form the VR scenarios were created and imported. Then, the programming process was carried out, consisting of the creation of a set of scripts to provide functionality to the objects and allow user interaction.

Four scenarios were developed to represent environments in which activities related to food and cooking take place. Three of the scenarios aimed at treating mobility problems in the hands, such as the grasping of objects or the rotation and prono-supination movement of the wrist. The fourth scenario is intended to improve problems of a cognitive nature, in particular, the identification of elements to perform a common task of daily living, such as preparing breakfast.

These scenarios were modeled and implemented in the form of a test, with specific goals that the user must achieve. In this way, the person who participates in the test can feel more motivated to reach the established objectives in comparison with traditional rehabilitation sessions. During the test with VR scenarios the user trains and progressively improves their abilities, reducing their functional limitations. In the execution of each environment, the user knows their progress in the pursuit of the objectives to be achieved through the use of visual or sound signals. After finishing the objective, a report is generated with data of interest on the specific skill being worked on that (Table 1) together with a live visualization of the test, allowing healthcare professionals to assess and check the user's evolution.

Table 1. Example of the data recorded in the Fruit Bowl scenario.

User	Test Time (Min.)	Left Hand						Right Hand					
		ABD	ADD	PF	WE	PE	PI	ABD	ADD	PF	WE	PI	PE
User 1	1.02	0°	76.52°	34.25°	54.79°	102.51°	52.40°	31.37°	36.64°	50.58°	38.05°	39.00°	131.54°
User 2	2.01	44.77°	48.33°	22.37°	71.48°	179.92°	18.19°	63.53°	80.06°	37.53°	71.83°	31.51°	179.87°
User 3	0.51	9.45°	57.74°	0°	45.477°	33.14°	23.59°	0°	0.24°	0°	5.51°	9.36°	0°
User 4	2.18	79.48°	81.29°	80.17°	45.88°	123.9°	45.16°	0°	76.52°	52.30°	11.59°	22.45°	52.86°
User 5	0.46	25.13°	48.05°	53.14°	54.83°	47.27°	36.45°	92.46°	35.22°	36.95°	74.72°	28.21°	105.20°
User 6	0.58	77.09°	53.85°	45.46°	40.11°	138.64°	14.96°	0°	5.57°	29.53°	0°	3.76°	2.12°
User 8	3.25	63.23°	85.38°	64.09°	41.87°	178.62°	36.01°	53.84°	95.71°	30.29°	69.38°	0°	178.92°
Mean	1.25	37.39°	56.40°	37.44°	44.30°	100.5°	28.35°	30.15°	41.25°	29.65°	33.89°	16.79°	81.31°

(ABD) Abduction, (ADD) Adduction, (PF) Palmar Flexion, (WE) Wrist Extension, (PE) Prono-supination External, (PI) Prono-supination Internal.

When starting the application, a home screen is displayed in which the user's first and last name must be entered. This information is later used as a means of identification in the activity report. After the user's data has been inserted, the VR application starts and the user sees an initial scenario through which he or she can select each work environment or end the application.

4.1. Description of Environments

- *Fruit bowl* scenario: Simulates the living room of a house; the mission proposed to the user is to place a series of pieces of fruit in a fruit bowl (Figure 2). The therapeutic objective of this scenario is to improve the grip and manipulation of the elements (which have different forms) with the hands. Thus, the use of different pieces of fruit allows the training of different grip modes, and the action of placing them in a fruit bowl allows the practice of hand movement combined with the grasping of elements. The movement that the user has to perform is spherical power grasping, implicating the long finger flexors to grasp and long finger extensors to release each fruit.

Figure 2. Fruit bowl scenario.

- *Tap* scenario: Simulates a kitchen; the objective proposed to the user is to fill a jug with water (Figure 3). To meet the goal, the user must open the screw tap using a rotational movement, fill the jug, and close it again. The aim is to improve difficulties present in the movement of the wrist. The action of turning the screw tap to open and close it, which allows training the rotation of the wrist in both directions of rotation while at the same time training a common action of daily life. The user has to perform a precision disc grasp. In addition, with this dam the user has to rotate the wrist to the right or left depending on whether they want to open or close the tap.

Figure 3. Tap scenario.

- *Cutlery* scenario: Again, the scenario represents a living room of a house; the action proposed to the user is to grab a knife and a fork and cut a piece of meat (Figure 4). The purpose of this scenario is to improve the grip and handling of cutlery. Users may have problems with the handling of cutlery at different meals of the day, which can limit their independence. The use of VR provides a safe, realistic, and motivating means of training. In this case, the movement and grasp implicate more manipulative dexterity. The user has to apply precision grasping with three fingers or with a thumb and finger. The movement implicates the flexo-extension of the elbow and rotation of the shoulders.

Figure 4. Cutlery scenario.

- *Breakfast* scenario: This environment, unlike the previous ones, aims to improve a problem of a cognitive nature related to the identification of elements to carry out an activity of daily life (Figure 5). Its execution implies working on the movement of the hands. Eating and cooking are common tasks in our daily lives, and are an ideal way to train those difficulties in identifying elements to perform certain tasks. In this scenario, the user must find several types of cutlery and different foods commonly present at breakfast, such as milk or cereals, and others that have nothing to do with it, such as a lemon or chicken breasts. In this way, the user has to select the food needed to prepare breakfast and the appropriate cutlery to take it. In this case, the grasp again implicates the whole hand, both spherical and cylindrical power grasping, involving the extensor and flexors muscles of the fingers. In addition, the user has to move over the space in order to transport objects from the worktop to the table and turn him or herself.

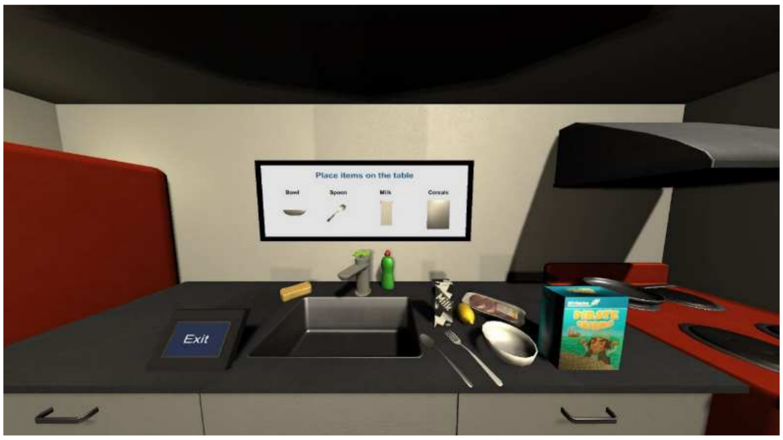

Figure 5. Breakfast scenario.

4.2. Visual and Audio Signals

To make the different environments more realistic, audio has been added to the different actions that take place during the execution of each environment. In addition, visual and audio cues have been added in order to provide feedback to the user on their progress in achieving the objectives of each test.

In the Fruit Bowl scenario, audio is played to simulate the real sound of hands touching the fruit. Regarding the tracking of the objectives, 3D models of the different pieces of fruit are used to create a panel where each fruit is displayed in black and white. Each fruit on the panel is associated with the real object that the user grabs with their hand; when a piece of fruit is placed in the fruit bowl, its representation on the panel changes from black and white to full color, and a sound is emitted each time one of the fruits is placed in the fruit bowl. In addition, after all the fruits have been placed in the fruit bowl a special sound is emitted to indicate the end of the game.

In the Tap scenario, when the screw tap is moved audio is played to simulate the sound it would make in reality, and the audio simulates the water flow. A panel with three objects representing a star was added, with each star associated with a game goal; the achievement of each goal illuminates its corresponding star and emits a sound. In addition, when all three objectives are achieved a special sound is emitted to indicate the end of the game.

In the Cutlery scenario, a sound is played simulating the cutting of the meat. The progress in the activity can be checked through a light bar and a percentage indicator, which vary as cuts are made. When the bar reaches 100%, a sound is played to indicate the end of the activity.

Finally, the implementation of the Breakfast scenario is carried out in the same way as the Fruit Bowl scenario; that each time one of the breakfast elements is placed on the indicated table, its representation on the panel changes from black and white to color, and a sound is played.

4.3. Data Export

One of the objectives of the project is the export of the data generated during the activity in the different scenarios for subsequent evaluation by a therapist. Thus, after the activity is finished a report is generated with different data of interest for the evaluation of the user. On the one hand, the maximum value (in degrees) that each hand is able to move in the X, Y, and Z axes is saved; thus, the lateral, vertical, and rotational movement of each hand can be evaluated. In addition, the name of the activity, the time of duration, and the date of completion are recorded. Table 1 shows an example of the data recorded by the Fruit Bowl scenario from the test sessions with entities and organizations.

To make it easier to keep track of different users, the application generates a separate file for each user and saves their activity logs in an orderly manner, taking into account the user's data indicated on the main screen of the application. If the user later uses the application again, the application will check to see whether a file already exists for that user. If it exists, it will continue to save the user's data. Otherwise, it will create a new file. This facilitates the process of following up on the situation of each user.

5. Results

After the application test was finished, different discussion groups were organized with entities and organizations from the social and health sectors. The purpose of these meetings was to assess the usability of the application, its suitability for the rehabilitation of the pathologies to be treated, and the users' reaction to the use of VR as a therapeutic tool. Before starting the exercise, users were provided with an explanation about the VR device, the tasks and the ability needed to work in each of the scenarios.

According to the methods applied and the questions asked during the focus groups with both professionals and users, several interesting features emerged.

In response to the above questions, most users indicated that the glasses were comfortable, except for one user who highlighted their weight as a negative. On the other hand, users and therapists saw it as very positive to not have to use controls. Regarding the design of the scenarios, all users were satisfied with the environments represented and highlighted as a positive the performance of daily life tasks as a means of rehabilitation. Regarding its usefulness in the rehabilitation process, the therapists verified that the activities presented in the virtual scenarios were correctly adjusted to the therapeutic intervention of the pathologies to be trained. In addition, both users and health professionals highlighted the way that the proposed activities made the rehabilitation process motivating and entertaining. Regarding the removal or addition of components to the scenarios, several users suggested an increase in the size of the text of the instructions. Likewise, the therapists recommended the incorporation of instructions in audio format. All users expressed feeling good during the development of the test. Only one of the users reported slight tiredness at the end of the exercise. None of the users felt dizzy, something that frequently occurs when using VR systems.

In the different organized discussion groups, all of the tests carried out were completed, and it was concluded that the developed application can be a powerful tool in rehabilitation sessions. It must be emphasized that these activities represent situations of daily life and that their implementation makes them motivating, entertaining, and safe.

6. Discussion

This project aimed to create VR scenarios as a tool during the rehabilitation process for people with disabilities. In order to do this, an application was created consisting of different environments that simulate everyday life situations configured in a way that allows training in different physical and cognitive abilities. In this section, the main developments and designed virtual scenarios are presented, highlighting their application for improving the rehabilitation process of people with disabilities.

In this article, the benefits of using an HTC VIVE device in combination with the Leap Motion device have been demonstrated. However, other devices of great interest are starting to emerge, such as the Oculus Quest. This VR equipment stands out for its lower cost and for being autonomous (that is, it does not require a computer or external sensors to configure the VR space), as well as for incorporating hand tracking into the device itself. These characteristics make it a very attractive device and invite future research on new more affordable and accessible devices, which could facilitate its implementation in homes and medical centers. We were able to find works [24] in which these devices are beginning to be used, and in which a resulting simplification can be observed in terms of installation and configuration of the VR space. Taking into account the above, it would be of great interest to carry out a comparative study between HTC VIVE and Oculus Quest. This would make it possible to observe in detail the advantages and disadvantages of each device and consequently choose the most appropriate for particular rehabilitation processes.

Leap Motion device is an optical system capable of tracking the movement of a person's hands and fingers, which allows her/him to interact with the different environments directly without the need for controls. The incorporation of this device was an added value in our project, as several work environments under study were intended to work with mobility problems in the hands, which is undoubtedly carried out more effectively by avoiding the use of controls as a means of interaction with the virtual space. In addition, at a general level it allows a greater immersion of the user in any type of environment. The cost of such a device is approximately USD 90, a very low cost considering the benefits it brings to the project.

After analyzing different tools existing in the current market in the Background section, the main differentiating features of the tool proposed in this project are highlighted, along with possible points for improvement.

In the study "Immersive Virtual Reality in older people: a case study" [6], one of the participants suggested improving the ergonomics of the controls. Our proposal would contribute to eliminating the ergonomics problem of the controllers, as the integration of the Leap Motion device avoids the use of the controllers, allowing the use of the hands as a means of interaction with the VR environments. In addition, it would provide greater realism and a wide range of possibilities in terms of interaction in the scenarios. The difference would be remarkable; think of the movements a person can make with the joints of one hand compared to the limitations of interacting with a controller as a medium.

On the other hand, programming our scenario would allow an option to be added to the interface in which we could configure the inclination of the camera in charge of capturing the elements of the scene. In this way, we could adapt this inclination to the user's problems. In the study in question, we would have avoided having to recline the wheelchair of the user with dorsal kyphosis.

In the analysis of the tool proposed by the Polytechnic University of Barcelona [11], we can highlight as very positive that the scenarios were developed by the researchers themselves; this allows better adaptation of the environments to the pathologies to be treated. The need to interact with controls can be a limitation for certain users, as, due to their pathology, they may have problems with the grip or with pressing the different buttons. This inconvenience can be solved using the Leap Motion device.

In a study similar to the previous one [25], in addition to using personalized scenarios, the Leap Motion device was used as a means of interaction. However, unlike our proposal, less realistic scenarios were observed, with an appearance more similar to a game than to real life. The same was the case in the interaction with the elements of the stage, which were not entirely realistic. For example, to open or close a faucet the users were required open or close their hand, instead of having to make the opening movement.

The WalkinVR application [12] provides both users and healthcare professionals with a wide range of possibilities by making all the games in the SteamVR catalog accessible to people with disabilities.

In fact, in the SteamVR catalog there are experiences derived from the application of games for health, with a focus on their impact on motivation, therapeutic results, and the behavior of users. However, these applications fail in the adequacy of the principles of universal design, and there are not any guidelines of accessibility oriented to the developers of the virtual environments [26].

Nevertheless, when using commercial apps as a complementary resource in rehabilitation sessions with people with disability it is possible to find several drawbacks, such as lack of customization, as these are general-purpose applications with few configuration options. Another difficulty is language, as most of the applications are only in English, which can negatively affect the VR experience; for example, non-English speakers may not know the objective of the game. For the most part, commercial applications are complex, their instructions are not easy to understand, and they do not give feedback to the user to guide him or her during the game. [27]. The need to use the controls to manage the elements in the VR environment is an important barrier and handicap for people with disabilities involving movement limitations in their arms and hands.

In a review of the application of Virtual Reality in Complex Medical Rehabilitation, it was concluded that "the use of virtual environments has proven effective for the recovery of impaired motor skills in people with disabilities". Nevertheless, it is necessary to provide personalized scenarios, goals, and tasks in order to achieve the maximum possible improvement in physical and cognitive skills as well as to register the results obtained during the sessions for each user [28].

Therefore, in the present project, a customizable VR application has been created to improve the rehabilitation process of people with disabilities. The virtual scenarios can be adapted to the needs of the user, who can interact with the environment directly with his or her hands thanks to the Leap Motion device, avoiding the use of controls. The visual and auditory feedback offered through the application is another strong point, and is a differential element compared to other commercial applications.

During the execution of each environment, the user receives feedback in order to always know the goal of the game and their progress in it. After finishing the task, a report is generated with data of interest on the specific skill that is being worked on, allowing the therapist to assess the evolution of the user.

During and after the development of the presented scenarios, the researchers were advised by health professionals from rehabilitation centers. Several meetings and trials with real users were carried out in order to configure and improve the scenarios and the inputs and outputs of the application. This collaborative work allowed for the creation and design of interactive solutions in which virtual scenarios meet the preferences, needs, and specifications of both professionals and users. Just this type of implication from all stakeholders suggests that it is possible to develop useful, practical, and relevant scenarios for the process of rehabilitation.

Future Research Directions

A new VR application is currently being developed that will allow even greater customization of the scenarios. This application will have an initial menu through which a professional will be able to select the virtual scenario and configure the available options to adapt them to a specific user. Several of the customizable options will take into account the degree of difficulty of performing the activity, both physically and cognitively. Different scenarios are currently being developed:

- An environment recreating an outdoor orchard: The user has to collect different vegetables indicated in the initial instructions. The scenario will allow training in both physical and cognitive skills. The professional can configure the main features, such as the level of difficulty or the height where the vegetables are located, to adapt the task to the progression of the person.
    - To train physical abilities, the scenario can be oriented to strengthen the thoracolumbar musculature in people who use a wheelchair. One of the tasks implicates that the person must collect tomatoes, located at different heights, and place them into boxes. The height and size of the tomatoes can be adapted by a professional according to the skills to be trained.
    - Concerning the training of cognitive ability, the orchard has tomatoes as well a different types of vegetables. Therefore, the goal can be to complete each box with a different combination of vegetables, indicated in the initial instructions. The number and variety of vegetables can be configured by the professional.

- An indoor supermarket as a virtual scenario: This environment proposes a great variety of options related to the performance of daily life activities, and will be able to present them to the user to practice during the task. The proposed activities that are being developing are:
    - From a shopping list, take the listed products
    - Starting from a cooking recipe, acquire all the necessary ingredients to prepare it
    - Practice paying for the purchase and handling money
    - Purchase of products without exceeding a previously set budget.

These scenarios simulate situations of daily life, although the development of other environments focused on other areas, such as work, leisure, and sports, is contemplated as well.

Our research team is studying the possibility of measuring a greater number of parameters during the execution of the application. These parameters could provide information about how the user feels while performing an activity, as well as more data that can provide more information to the therapist when evaluating a user's progress. Possible parameters include heart rate, sweating, time to achieve each goal in the game, or the number of attempts.

In order to obtain a functional and usable tool, the research team is working collaboratively with NGOs, professionals, and people with disabilities. During work meetings, participants use the virtual scenarios in progress and provide their opinions about different features and improvements to the application. The development of the whole project thus has a perspective of user experience.

7. Conclusions

The present project is an innovative and technological development directed to improve the rehabilitation process of people with disabilities as a complementary resource during their intervention. The virtual scenarios that the application incorporates are designed considering the skills to be trained by the users. Training based on activities of daily living were chosen. In this way the user, in addition to improving their physical and cognitive ability, is able to achieve greater independence in their daily life. Setting clear goals in each VR environment and providing feedback to the user during each task helps to increase their motivation in training. In addition, the high realism of the scenarios developed allows greater immersion, contributing to a better experience in carrying out activities. The Leap Motion device is an added source of value to the project, allowing interaction with the application without the need for controls, which is a clear advantage compared to most of the previous studies analyzed. The virtual scenarios developed in this project have potential benefits:

- People with disabilities and rehabilitation professionals can benefit from the use of VR as a complementary technological tool during the intervention process. Using the same space or room of the hospital or clinical center, VR can simulate a great variety of scenarios, both indoor and outdoor.
- The use of personalized scenarios offers clear advantages over the use of commercial options, allowing activities to be adapted to the abilities and needs of each user.
- The application offers clear advantages to complement the traditional rehabilitation process and intervention for people with disabilities. It allows health professionals to have control of the whole application, configuring the appropriate activity for each user and knowing their progression. He or she can monitor the evolution of each user through the results obtained from his or her motor and cognitive inputs thanks to the registers captured by the application.
- The Leap Motion device is a very useful tool when combined with the VR glasses to create a global and completely immersive experience. This combination allows for dispensing with controllers, as the user can use their hands and fingers to directly interact with the scenarios. These movements lead to improvements in coordination and fine dexterity ability.

In the future, the final goal of the project is to consolidate a solid application with more virtual scenarios simulating activities of daily living and to implement this low-cost tool as a complement to the routine intervention of the rehabilitation centers in our environment

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