Virtual Reality for Locomotion Rehabilitation

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Abstract
Locomotion is a very important ability for our well-being. Unfortunately, there are many conditions and diseases, such as stroke, that can affect this ability and degrade the individuals quality of life. In recent years, the impact of these conditions has been increasing and patients have a greater need to resort to physical rehabilitation. Therefore, there is an urgent need to improve and develop better solutions in physiotherapy. Virtual reality (VR) is a promising technology that has been proven to have significant benefits in physiotherapy. However, there is little implementation and subsequent adoption of VR alternatives in locomotion rehabilitation. In this research, we built an immersive VR system, called Locomotiver, that supports exercises for locomotion rehabilitation based on the needs and expectations of our physiotherapists partners. We also conducted an experiment where several therapists used the prototype and provided feedback, commentaries and answer interview questions. Participants also responded to a questionnaire based on concepts inherited from theories of adoption. Finally, we made a qualitative thematic analysis on the results of the experience and correlated them with the outcomes of the questionnaire. In the end, we concluded that the professional physiotherapists had indeed the usage intention and will to adopt the Locomotiver as a VR solution and apply it in their daily practises.

Keywords: Virtual reality, physiotherapy, locomotion, rehabilitation, technology adoption, immersive technology

1. Introduction
Locomotion is one of the most significant abilities of humans beings. It enables people to move around and it is very important to maintain our quality of life. However, over the last years, there has been a raising of diseases and conditions that affect people’s locomotion abilities. This enhances the importance of physical therapy for these patients that has been proven to be paramount to their partial or full recovery. One technology that has been established as one of the most influential of the future is virtual reality (VR). There have been many studies conducted on the benefits of VR in medical context including physical rehabilitation and recently, new progresses on the development of VR systems to be used as a complement or substitution of standard therapy. However, despite the numerous studies on the benefits of VR as a viable solution to improve the experience and results of physical interventions, there is still an issue with the slow adoption of this technology in real clinical environments. This phenomena is even more evident in locomotion therapies as, due to its complexity, there are almost no VR systems that support this type of rehabilitation. One of the most important issues is related to the physiotherapists and the seeming lack of support given to them.

1.1. Objectives
In this work, we had the goal of helping physiotherapists to include VR in their locomotion rehabilitations. We proposed the Locomotiver VR system as an immersive VR complement to locomotion therapies which included exercises for lower limb recovery. After the development phase, we wanted to assess the physiotherapist’s will to adopt it as an alternative or complement to their daily practises.

1.2. Contributions
This research presents itself several contributions to the medical and scientific community in a lot of aspects:

- We established a clear understanding of the state of the art on the application of VR in physiotherapy and the relationship of professional clinicians with such technology.
- Development of a VR system prototype capable of deploying exercises for locomotion rehabilitation, based on meetings with professional clinicians.
• Conduct a study with professional physiotherapists that included a qualitative thematic analysis on the clinician’s opinions about implementation of a VR system in these therapies.

• Results from a questionnaire with 20 statements regarding the usage intent of physiotherapists to adopt our prototype as a VR solution.

2. Theories of Adoption and Acceptance Models
Technology advancement is a constant product of innovation in human history. Over the last decades, the adoption of new technology has been the subject of multiple cross-field studies. From social to psychology to the information systems, multiple researches have been conducted to better understand what drives people and societies to include innovative technology in their daily lives.

2.1. Theory of Reasoned Action (TRA)
The TRA is a theory that is used to predict how humans will act based on their previous attitudes and behavioral intentions. The key constructs of the TRA are attitude toward behavior and subjective norm. [6].

2.2. Technology Acceptance Model (TAM)
The TAM has been a widely accepted model to explain why people use and adopt new technologies. It is often associated with the information systems field and its research context [19]. The TAM is built upon two key constructs: perceived usefulness and perceived ease-of-use.

2.3. Motivation Model (MM)
The (MM deals with motivational theories to explain human behavior. Vallerand [22] explores that MM makes clear that intrinsic and extrinsic motivation are important concepts to be considered in order to better understand how people act.

2.4. Theory of Planned Behavior (TPB)
The TPB extends the previously mentioned TRA. However, the TPB adds the construct of perceived behavioral control [1]. This perception is related to the degree to which a person believes they control any given behavior.

2.5. Model of PC Utilization (MPCU)
This MPCU expands the idea of adoption of new technologies with the key constructs of job-fit, complexity, long-term consequences, affect towards use, social factors and facilitating conditions [20]. This model presents an opposing position to the previous TRA and TPB and it is suited to predict user acceptance and adoption of information technologies.

2.6. The Innovation Diffusion Theory (IDS)
The IDS has also been a subject of a study by Hess et al. [8] on adoption with VR technology. Ash et al. [4] expanded that the IDS was a useful framework for analyzing the desirable and undesirable consequences of adopting, in a hospital, a computerized provider order entry system. This theory states that there are four main concepts that influence the spread of new ideas: innovation, communication channels, time and social system.

2.7. The Social Cognitive Theory (SCT)
The SCT by Bandura et al. [5] states that the behavior of users, regarding a technological system, is heavily influenced by their expectations of such system’s performance and the related gains either for job improvement or personal gain.

2.8. Unified Theory of Acceptance and Use of Technology (UTAUT)
The UTAUT is a technology acceptance model that integrates elements from many other models [23]. It is a very versatile and comprehensive model that can be applied in multiple fields [13]. The four key constructs of this model are: performance expectancy, effort expectancy, social influence and facilitating conditions. The first relates to the degree the user thinks the technology will help him or her at the job. The next concept, effort expectancy, regards the perceived ease of use by the individual. The social influence is related to the social factors that affect the individual’s judgment. Finally, the facilitating conditions regard the user’s beliefs that his or her organization have the technical infrastructure to support the innovation. This model has been used in multiple studies to assess the usage intent of users regarding technological systems [15].

3. Related Work
3.1. Virtual Reality in Physiotherapy
VR has been one of the most promising technologies to revolutionize physiotherapy. VR is the term used to describe a technological system that creates a simulated world or environment for the user to experience usually by the means of a head mounted display (HMD). In physiotherapy, VR has emerged as an alternative to the increasing numbers of individuals with limiting conditions such as stroke, and its results are becoming clearer. A systematic review [7] compared the difference between the addition of VR, as a complement, to therapy and the complete replacement of later with VR based rehabilitation (VRBR) applied in a locomotion rehabilitation. It concluded that VRBR is more effective and produced better results. As VRBR has been proven to be effective, some VR systems have started to be build and their results assessed. Kaminer et al. developed a prototype that inte-
grated the Oculus Rift, the Kinect and a pair of haptic gloves to create a VRBR solution for after-stroke hands strength [9]. The game would be displayed on the Oculus Rift which fully immerses the player and increases its focus. AlMousa et al [3] also established a VR system for upper limb treatment. After a requirements assessment of therapists and patients needs, they developed a VR prototype and found it to increase motivation and engagement in patients.

Most research related to VR in physiotherapy addresses upper limb rehabilitation. Powell et al point out several reasons that include the increase complexity of systems for locomotion rehabilitation [14]. VR systems for locomotion have notable challenges as they usually require treadmills or cycling devices that increase the cost of the system. But there are already some solutions for these interventions. Keime et al. developed a treadmill system that used the Oculus Rift to immerse the user in a city environment [10]. One way to develop VR in physiotherapy is by means of exergames. These games offer a more fun and engaging environment that motivates the player to complete the tasks. Some exergaming projects in VR include Motion Rehab AVE 3D (MRAVE) [21] and "Snowballz" [25].

Figure 1: Snowballz - an exergame that uses the HTC Vive.

3.2. Empowering Physiotherapists
Physiotherapists are some of the most important stakeholders in rehabilitation interventions, therefore it is fundamental to have their perspective on the implementation and introduction of VR as an intervention option. Schmid et al conducted a study [16] that collected insights on experiences and expectations of physiotherapists specialized in the rehabilitation of after-stroke patients that used a non-immersive VR system. Most therapists felt very confident on the effectiveness of the VR system in the context of their therapies. Some mentioned that they felt motivated by applying VR even though they were not playing along with the patient. A recent online survey [12] on the clinical use of VR and exergames by Canadian physical therapists was conducted to identify barriers, facilitators and determine the learning needs of the physicians. The predictive factors of using VR in clinical environment included the technologies usefulness and therapists confidence in conducting the interventions with those systems. The barriers that came out of this study refer to the lack of funds to implement this technology, not having a dedicated space for the practise as well as supportive staff and appropriate patients. To apply these VR systems, therapists need to have not only the necessary requirements fulfilled but need to understand as well how to use, interact, setup the systems and be able to adjust it accordingly to the patients situation.

3.3. Virtual Reality Systems
Researches prior to 2014 often refer to VR as any kind of system that can generate a computer simulation, regarding of utilizing an immersive HMD or not. Nowadays, the concept of VR is to use a headset to substitute the persons sense of sight with a virtual world. There are already very functional and cheap mobile VR systems such as the Google Cardboard and the Samsung Gear VR. However, they utilize a smartphone and the experience is very limited. Desktop VR systems like the Oculus Rift and HTC Vive are much more powerful and lately have been used in a variety of studies related to VR. The Oculus Rift has already been used as a tool in many researches in the medical field such physiotherapy [24]. On the other hand, the HTC Vive is a very high-quality device that can produce great virtual scenarios. This system enables the movement as well in a room-scale configuration because of its good tracking which has been proven to be a more immersive experience compared to a stand-up only [17]. Many applications and researches have taken advantage of this system to build interactive VR experiences and exergames as well. Suznjevic et al [18] compared the performance and quality of experience of both the Oculus Rift and the HTC Vive and concluded the Vive to be slightly better in some aspects that included a better quality of experience.

4. Understanding Physiotherapists
This work aimed to understand some of the potentialities of VR adoption in physiotherapy, particularly in locomotion rehabilitation. Based on the scientific readings, the technology adoption theories we designed a study to test the willingness of professional physiotherapists to integrate a VR prototype solution made specifically for locomotion rehabilitation. The study would have two main phases. One for the development of the VR prototype and a second for the evaluation and analysis of the results. In both cases, the participation and understatement of professional physiotherapists was crucial. Therefore, we took advantage of our partnerships to develop a collaborative and iterative process of proto-
type development.

4.1. Preparation Phase
Since our team did not have a lot of experience in the field of locomotion rehabilitation, we had to prepare some introductory questions in a semi-structured interview format. Most questions were very opened to allow the therapists to expatiate their conversation and provide information they thought was useful. These questions included:

- What kind of locomotion rehabilitation do you usually conduct?
- Could you provide us some generic or specific exercises related with locomotion interventions?
- Do you leave patients alone or do they always need someone looking out for them?

4.2. Field Research
We partnered with professional physiotherapists from Instituto Superior de Ciências da Saúde Egas Moniz and Hospital Prof. Doutor Fernando Fonseca, E.P.E. and visited them on their facilities. In this field research, we observed the therapists working with several neurological and musculoskeletal patients and perform a variety of exercises related to their locomotion therapies. We registered these exercises and also managed to speak with the professionals that explained some of the processes behind the rehabilitations. Over time, follow-up meetings took place to iterate on the Locomotiver’s functionalities.

4.3. Design Implications
After the field research, we started to better understand not only some of the physiotherapists practices, but also how could we improve them by recurring to VR. With this knowledge, we had some base design implications for the development of the prototype.

Regarding the the patient persona, the implications included: be comfortable, safe and easy to use; easy to learn and intuitive; provide motivating and fun experiences; have engaging and immersive environments; present gamification. On the other hand, it is important to note that the therapists are the ones who conduct the rehabilitation processes and decide whether or not the system is worth to apply. The Locomotiver’s implications for therapists were: require little effort to learn and understand the use of the system; provide a useful experience for their daily practise; provide reliable data from each session; provide reliable data from each session; function properly with limit systematic errors; allow customization of exercises; utilize unique features related to VR. With all of this in consideration, we were able to start developing our Locomotiver prototype.

5. Locomotiver
We built and proposed the Locomotiver as a platform to deploy exercises that leverage that technology specifically for the treatment and rehabilitation of locomotion disabilities.

5.1. Architecture
The Locomotiver was with hardware and software technology provided by the HTC Vive. We chose the Vive as it is very easy to use and setup and it already included all the hardware that makes VR work. The headset is very precise, with 360-degree tracking and realistic graphics. The controllers have an incredibly rigorous tracking and are very intuitive to use. These devices are being tracked by the Vive base stations. The tracking system emits infrared pulses at 60 per second that detect the headset, controllers and trackers with millimetric precision.

5.1.1 Vive Trackers and Full-body Tracking
In addition, we decided to included Vive Trackers and straps. Each patient is required to attach two trackers, on its feet, that function as markers and allow the system to recognize their position and consequent movement. The inclusion of these devices allows a full-body motion and visualization in a regular session.

![Setup of the Vive Trackers on the patient’s feet](image)

Figure 2: Setup of the Vive Trackers on the patient’s feet

5.2. Unity 3D
The Locomotiver was built using Unity3D. Unity brought a lot of advantages to the development of the prototype. Some convenient factors associated include not only the large availability of assets, open-source code, tutorials and sample projects. Furthermore, Unity also had a significant community of VR developers which was also very important as it allowed us to minimize errors and optimize processes. The scripts for the Locomotiver were written in C#.
5.3. Exercises

5.3.1 “Walking Forward”

We started by creating a simple VR environment. We separated the visualizations (therapist and patient) by including two different cameras, one integrated with the Vive for the patient to experience the 360 environment as a P.O.V (point of view) and a main one for the physiotherapist to have a 3rd person view and an user interface that controls the sessions. Then, we started to build the first exercise. The ”Walking Forward” consisted in a small corridor that extended from one side of the play area to the other and had two borders. The purpose of the exercise is to allow the patient to go from the starting point to the other side and back without touching the borders. Each exercise had a starting point and a goal on the opposite side, indicating the patient to move towards that goal. Once the patient arrives, the goal moves to the opposite side and so on.

After the second iteration of meetings and feedback with the partners at Egas Moniz, we took some of the commentaries and implemented them to establish the final version of the Locomotiver.

5.3.2 ”Barriers”

In this exercise, the user had to surpass obstacles in the form of barriers. The barriers were customizable by the physiotherapist at the start. These were made so that they would turn red if stumbled upon and would emit a sound effect as feedback. On the other hand, the player would hear another sound when surpassing it successfully.

5.3.3 ”Zigzag”

We based ourselves on the feedback from the meetings to design our own zigzag exercise using cones as obstacles over a course. The purpose of this exercise consists in working around each cone without touching it and reach the goal to complete the sets.

5.4. Physiotherapists User Interface

We designed the therapist interface to be very intuitive, minimalist and easy to understand. We also made it so it enabled the most control and customization as possible over the system.

This interface allowed easy access to the each of functionalities of setup exercises, customization of the Locomotiver (settings), visualization of metrics, POV of the patient among others. On the setup of exercises, the therapists can customize each exercise’s parameters such as the timer, number of repetitions and the custom variables unique to the exercise, such as the barriers height on the ”Barriers”. The settings included the calibration, toggling of parallel bars and changing the camera. The metrics menu displays the results of the exercise being performed.

5.5. Patient’s User Interface

The patient interface was made to be as simplistic as possible to promote the best VR experience possible. Nevertheless there are significant components we describe in this section.

5.5.1 Virtual Body

On the Locomotiver, we opted for a minimal representation of the virtual body, accordingly to Kondo et al [11]. We established visual components for the feet of the player. Two low-poli 3D models of shoes on the same position as the HTC Vive trackers (required to be used on the subjects feet). The
player’s hands are represented by the HTC Vive’s controllers included on the Vive’s library. At last, the head is presented in VR as a 3D model of the Vive headset to keep a level of visual consistency.

5.5.2 VR Environments
In order to create a good VR experience for the immersed patient, it was important to develop some great visual compelling environments. We created three environments - "Locomotiver Gym", "Forest" and "Oasis" depicted respectively on 4, 3 and 5. All three environments have very simplistic assets and objects to maintain the optimization required for VR.

6. Evaluation
Once the Locomotiver prototype was finalized, we proceeded to the evaluation phase. During this stage, we settled several objectives that included the assessment of the quality of the prototype as well as the search to understand the adoption expectations and usage intent of the professional physiotherapists to integrate and apply it in their daily activities. We started by establishing some research questions related to the adoption of our VR solution and the impact and implications of it.

6.1. Research questions
The main research question we had related to the usage intent and adoption of the proposed prototype and stated:

• Do physiotherapists have the intent to adopt the Locomotiver, as a VR locomotion rehabilitation option, in their daily practices?

By answering this main question, we can have a sense if the processes we took during the previous phases actually improve the intent to use this technology. Other questions included:

• Do physiotherapists believe the Locomotiver will motivate their patients and bring benefits to their rehabilitations?
• Is the system easy to use and understand? If not, what can be improved?
• Do therapists believe that the system can improve their activities?
• What are the biggest barriers to the immediate application of the Locomotiver in a real life scenario?

6.2. Participants
The evaluation was carried out with our partners from the "Instituto Superior de Ciências da Saúde Egas Moniz" and also professional clinicians from "Hospital Garcia da Horta". The 9 participants were all active in the physiotherapy area, whether as being an active physiotherapist or as a current professor on the subject and all had previously performed locomotion therapies.

6.3. Methodology
The experiment, we conducted, was comprised by the following stages: briefing, using the Locomotiver as the patient persona, using the Locomotiver as the physiotherapists persona, semi-structured interview, questionnaire and conclusion. All participants followed each one, in order, accordingly.

6.3.1 Briefing
Before the experiment begin, all participants were given informed consent forms that outlined the purpose and goal of the study as well as the information that concern their privacy, safety and personal data. After the initial briefing and transmission of the study purpose, we would proceed to explain the various phases that would come about. We would also ask the participants to utilize the think aloud protocol to maximize the feedback collected.

6.3.2 Using the Locomotiver as the Patient Persona
In this phase, the therapists experimented the Locomotiver using the VR devices and tested the system as if she was the patient.

Figure 7: Researcher helping a participant to setup some VR devices

When the participant was set in the VR environment, we would typically take between 2 to 3 minutes to leave her to freely explore the environment. They would comment of the environment and the exercises that we proposed.

6.3.3 Using the Locomotiver as the Therapist Persona
The physiotherapist persona relates to the clinician that is conducting the VR intervention. We proceeded to briefly explain the user interface and the
elements of it. However, we did not explain everything as we wanted to let the participant explore at will the system.

This was the phase that took the longest time of the whole experiment, mainly due to the time spend by the therapists explaining their suggestions and comments. We gave the participants total freedom to experiment the boundaries of the Locomotiver and explore new possibilities that could be implemented in the future.

6.3.4 Semi-structured interview

From the beginning we had a set of questions prepared to gather as much information about the quality of the system and the experiment itself. The semi-structured interview included questions such as: "What did you like the most about the Locomotiver?" or "Do you believe VR can bring benefits to patients? If so, what kind of benefits?". These questions were in place to stimulate the conversation. Since, most of the time, the therapists would not comment on these subjects directly, so we would take some time at the end of the experiment to touch on some of these points.

6.3.5 Questionnaire

At the end of each experiment, participants were asked to fulfill our questionnaire that was heavily influenced by the research work of Alaiad et al. [2]. The questionnaire was composed of a list of 20 statements which the therapist had to evaluate with a 7-point likert type Scale. The values ranged from 1 to 7, 1 meaning the therapists disagreed completely and 7 they agreed completely with the given statement. This questionnaire was constructed based of some key concepts that support some models of technology adoption as we reviewed in previous sections. The concepts we considered most relevant for the adoption of VR technology were: "Performance Expectancy", "Effort Expectancy", "Social Influence" (Social), "Facilitating Conditions", "Trust", "Ethical Concerns" and "Legal Concerns". In addiction we categorized the concept of "Usage Intention" to map the research questions directly related with the adoption of VR.

At the end of each session, we would, once again, thank the participant for her time and kindness in helping the research.

7. Results

In this chapter, we present a thematic analysis of the semi-structured interviews and feedback collected during the experiments with the professionals. We also exhibit the results obtain from the questionnaire and establish a correlation between the collected data.

7.1. Thematic Analysis

Following the procedure mentioned in the previous section, each experiment, with the therapists, lasted between 25 and 45 minutes. We followed a standard methodology of a thematic analysis to extract valuable information from the interactions with the physiotherapists. The four themes found in the thematic analysis were as follows: VR: A new and more motivational experience in physiotherapy; Locomotiver: Limitations, Improvements and Suggestions; Patients fit for VR; Potentialities and Benefits of VR for Physiotherapists.

7.1.1 Theme 1 - VR: A new and more motivational experience in physiotherapy

This theme focus on how the professional physiotherapists perceived the VR experience as a better way to provide not only more motivational and fun rehabilitations but also introduce some of the benefits of this technology. The VR environments had very positive responses such as - "I think that the environments are very interesting. I particularly liked the one with the forest and nature.". Therapists justified that "[The Locomotiver] is a more playful, entertaining way to motivate patients to participate in their rehabilitation". In general, therapists agreed that the Locomotiver provided a much better way to innovate their interventions and introduce novelty factors in their patients routines.

7.1.2 Theme 2 - Locomotiver: Limitations, Improvements and Suggestions

This theme describes some of the opinions and feedback from the participants regarding the Locomotiver. Participants pointed the cable (that connects the HMD to the computer) as an issue for their movement saying: "The cable is a bit troublesome. I was afraid I would get wrapped in it and because of that I was a little uneasy when I walked around.". They also wanted more control over the customization of the exercises as well as adding more: "I think the therapist should be able to edit the obstacles. Maybe I should be able to display them in different positions across the room, make them bigger or smaller, longer or wither according to each patient." There was also comments on the possibility of collecting more data as well as establishing personal profiles of the patients, which would be very useful.

7.1.3 Theme 3 - Patients fit for VR

This third theme outlines the therapists views on the patients that would be fit for this kind of interventions. There was a general consensus that the
patients more fit to utilize the Locomotiver were patients with musculoskeletal disorders or orthopedic conditions - "I believe it is more fit for patients with musculoskeletal problems". Most therapists were not confident they could apply our solution with neurological patients, due to the complexity of their conditions and associate fragility. They argued: "Regarding the neurological patients, this may not be adequate. Some do not have a clear perception of their body in real life. That effect would be accentuated in VR, making it too exigent for them". They also provided feedback in using the Locomotiver with elders and athletes.

7.1.4 Theme 4 - Potentialities and Benefits of VR for Physiotherapists

This last theme covers the potentialities and benefits of VR identified by the participants relatively to their daily activities. Despite the comments on the limitations of the cable, therapists praised the hardware and how fast and easy was to setup, especially compared to other common technological systems in their practises - "The system is easy to setup and actually really comfortable. I also think it is good that we do not need that many devices to make it work" one commented. However, the main identified benefit related to the optimization of their practises as they felt the Locomotiver could help in this matter - "For me it would make many of my tasks a lot faster. Almost everyday, I have to take some time to setup the exercises. By using this system, I can setup and change the exercises very quickly and it gives back an exercise ready to be used.". In general, therapists understood the benefits of the Locomotiver in their daily practises. They seem enthusiastic and provided a lot of feedback for future developments and adoption of VR in physiotherapy.

7.2. Questionnaire

For the analysis of the questionnaire, We started by converting each entry of the likert type scale to numbers ranging from 1 to 7. Values closer to 1 lean to the "strongly disagree" opinion while greater numbers tend to "strongly agree". For each question, we calculated: mean, standard deviation, minimum and maximum values, median and interquartile range (IQR). We proceeded to create box-and-whisker plots that are displayed on 8 and 9

By analyzing the graph on the figure 8, we can observe that the answers to the first questions were overwhelmingly positive. This result may be a product of the positive feedback of the therapists, relatively to the Locomotiver and VR, particularly on the topics covered by the themes 1 and 4 of the previous analysis. The first statement (Q1) was directly correlated with the main research question regarded the usage intent of the physiotherapists to adopt a VR system in their daily practise. Q11, Q15 and Q16 were also part of the "Usage Intention" concept and revealed positive outcomes. This indicated the willingness of therapists to adopt the Locomotiver. The concept of performance expectancy also produced positive responses. However, Q12 was the most disagreed statement. On the other hand, all the statements associated with the effort expectancy had at least a median of 6 and IQR of 2. It was also very interesting to note that therapists believe their work environment provided the facilitating conditions that promote the use of a VR system like the Locomotiver. Participants strongly agreed with all three statements to this concept. Also, the social concept related statements, related to the patients, had positive outcomes.

The concept of trust was present of the Q13 and Q14 statements. While we can consider the outcome positive, therapists were more disperse in their answers. The remaining statements had a negative connotation and regarded the ethical and legal concerns. Note that most physiotherapists did not agree either with Q17, Q19 nor Q20, but Q18 represents a general concern among professionals. This one was related to the safety and well-being of the
patients, which unsurprisingly is a priority for the therapists. This is important to note for future developments of VR for locomotion rehabilitation.

8. Conclusions
In this research we explored the impact and adoption of VR in locomotion rehabilitation with professional physiotherapists. Innovative technology, like, VR has been the subject of multiple studies that prove its positive effect in physiotherapy. However, there was a lack of adoption and practicality of these solutions, particularly in locomotion rehabilitation. To face this issue, we partnered with professional physiotherapists to build a VR system that could deploy exercises, in a virtual environment, related to the rehabilitation of locomotion abilities. The Locomotiver included very customizable exercises that mapped real ones from traditional interventions. We have verified that it also provided a very engaging and motivating experience for the users. After the development of the prototype we posed a research question regarding the usage intent of professional therapists to adopt the Locomotiver in their own clinical practises. We designed an experiment where professional therapists would use the system and provide feedback on it. We analyzed the data using a qualitative thematic analysis of the collected opinions, commentaries and interview responses. Using a qualitative thematic analysis of the collected opinions, commentaries and interview responses, four themes emerged. These four themes were: "VR: A new and more motivational experience in physiotherapy" that related to the therapists perception of VR as a better way to involve and engage their patients and motivate them to participate more actively on the rehabilitation; "Locomotiver: Limitations, Improvements and Suggestions" described some of the hardware and software problems that may limit the usage intent of the therapists and require further implementations; "Patients fit for VR" indicated the types of patients that professionals considered apt to start using this type of solution, namely more autonomous musculoskeletal and orthopedic patients instead of individuals with neurological conditions; "Potentialities and Benefits of VR for Physiotherapists" stated the advantages physiotherapists identified such as a better optimization of their practises. In addition, we conducted a questionnaire supported by following adoption theories key constructs: performance expectancy, effort expectancy, social influence, facilitating conditions, ethical and legal concerns and usage intention. The results of the research have shown that professional therapists would be interested in adopting the Locomotiver as a VR rehabilitation tool in their daily practise. This suggests that the process behind the development enhanced the positive outcomes of the research. We believe that this research contributes to establish this a baseline to develop and introduce immersive VR technology, that significantly boosts the motivation of patients, optimizes intervention processes and improves the overall locomotion rehabilitation.

Future Work
As future work, we propose a research where the physiotherapists used the Locomotiver with real patients for a certain period of time, in a real life scenario. This would provide more information on the actual practicality and consequences of appliance of this type of intervention. Regarding our own research, we believe that we were limited by sample size of therapists that tested our solution. A bigger sample size would provide more information and possibly new findings. The previous material that included both the semi-structured interview and questionnaire could also be expanded to more detailed and specific questions to assess other results. Finally, additional research could be transposed to other areas of physiotherapy and rehabilitation scenarios.

References


