Using Virtual Reality domain to set up sports simulation as part of rehabilitation

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Abstract

For people with injuries that affect their mobility their mobility, regaining their independence and reintegrating into society is a daily challenge. These people are often followed by specialists who ask them to practice at home. However, it is difficult to ensure that patients perform them correctly and safely at home. at home. Our project aims to set up a virtual rehabilitation center to help these people perform these exercises correctly in order to ensure their rehabilitation in the best conditions.

Keywords : Sports, Rehabilitation, Antropy, Simulation, Virtual Reality, Haptics.

I Introduction

The fruit of our innovation will help people with motor disabilities, to ensure a rehabilitation and a re-education to the sports movements as well as to the gestures and actions of the everyday life. To achieve this innovation, we have relied on studies that affirm that Virtual Reality is a viable means for the rehabilitation of people suffering from a physical handicap. Others have allowed us to understand human behavior to reproduce it. These studies brought us a support in the realization of our scientific article. Through this article, we propose a solution allowing an accompaniment of the people suffering from physical handicap in their rehabilitation through a virtual environment. The rest of this article is organized as follows: Section 2 describes the way and the methods we have realized for this study. Section 3 presents the results we obtained. Finally, results are discussed in Section 4.

II State-of-the-art

II.I Scientific studies

Our first reading[1] presents a motorized wheelchair simulator wheelchair simulator . This simulator aims to allow people who need this means of locomotion to train in situations reproducing real environments and constraints. real environments and constraints.

To do this, this simulator relies on different technologies of virtual reality combining the visual, hearing as well as movement in order to immerse the user and to avoid the inconveniences (ex: motion sickness) that could be caused by virtual reality. This document indicates that virtual reality has already proven its effectiveness and usefulness in the simulation of training for aviation or for train drivers.

It also indicates that virtual reality is a very practical tool that allows to simulate situations and/or environment that would be difficult to reproduce in reality while remaining easy to use and safe for users. Moreover, according to recent studies, virtual reality increases user motivation.

This study[2] also highlights the usefulness of virtual reality for this kind of study on human behavior. In order to carry out this study, researchers have developed an experiment staging the avoidance of a collision between a participant and another pedestrian in the real world and in a virtual world. During this experiment, the participants' gazes were recorded using eye-tracking techniques and their movements were recorded using virtual reality equipment. This study couples the study of the gaze to the study of the kinematics (movement) of the subject because it has a fundamental role in the understanding of the environment and the decision making in this kind of situation. The results of this study showed that the collision avoidance behavior was the same in the real and virtual environment. However, the search for visual information was different. Virtual reality would therefore allow for a precise and qualitative study of human behavior in complex situations.

II.II Virtual reality, sports and video games

In the world of sports, and more particularly in the world of video game sports, competitions are becoming more and more known. These competitions are not necessarily physical because a video game is mainly played on a screen, but for a few years now, virtual reality game competitions have been making the news. In this section we will talk about a competitive video game and explain why it can appear in the field of sports.
Echo Arena is one of the first competitive virtual reality games exclusively designed to develop the field of Esport in virtual reality [3]. It is based on the simple principle of Ultimate, a team sport played with a Frisbee. The relationship between virtual reality and real sports is plausible. To adapt this to our subject, let's take the example of an injured Ultimate player who cannot resume training. This player would then avoid losing his experience over time thanks to this kind of game.

II.III Artificial Intelligence

Following this explanation of the correlation between virtual reality, sports and rehabilitation, we can see another field being added to the sportsmanship of the video game world. For the past few years, the use of artificial intelligence has been intensifying in the field of Esports. Initiated by Elon Musk and a startup called OpenAI, an opensource artificial intelligence was developed based on the complexity of the game DOTA2 (designed by the development studio VALVE) [4]. The goal of this artificial intelligence was to show its ability to be better than the best players in the world. This AI was able to learn and master all the specificities of the game in only two weeks. To show the capabilities of its artificial intelligence, OpenAI has confronted it to the greatest teams in the world. It was able to show itself dominant in some points in 1 vs 1 and 5 vs 5. We can therefore imagine a potential future between the AI developed by OpenAI and virtual reality game competitions, such as Echo Arena mentioned above.

II.IV Learned Motion-matching

Motion Matching [5] is a simple but powerful way to animate characters in games. Compared to other methods, it does not require much manual work once you have a basic setup: there is no need to structure clips in graphics, carefully cut or synchronize them, or explicitly create new transitions between states.

However, Motion Matching works best when combined with a lot of motion capture data, and all of this data comes at a cost: significant

memory usage, which only gets worse as the system grows and the number of situations in which it is applied increases. Researchers are increasingly interested in what is called "Learned Motion Matching"[6]. This takes advantage of machine learning to significantly reduce the memory usage of motion matching based animation systems. The basic idea is to train multiple neural networks to emulate the motion matching behavior. Emulating motion matching means that you can continue to iterate, debug and control the system as before - just apply the learned motion matching as a post-process to process the data! Once trained, Learned Motion Matching does not need to keep the animation data in memory, only the network weights. This means that memory usage does not increase as you add data...

II.V Combining haptics and positional tracking

A haptic device is a virtual reality technology that allows physical interaction with a virtual object. This system restores to the user the perception of touch (tactile sense) and the sensation of movement in space (kinesthetic sense). The user wears a garment or accessory that communicates his body movements to the computer. A software processes this data and allows the virtual body parts to reproduce the movements of the real body part. We can therefore use this kind of device to improve the immersion of the user but also his rehabilitation. Several technologies on the market are used, gloves, vests, chairs, bracelets, treadmills. However, the technology embedded in the TeslaSuit, a haptic suit manufactured by Tesla[7], has particularly caught our attention. In our case, the TeslaSuit could be adapted in simulation contexts, where the user's body would be put to severe tests. For example, a combat simulation, in which virtual blows could be felt. The use of this suit could be used in environments that would put more strain on the user's muscles. In addition, the TeslaSuit allows via some virtual reality tools, to use the positional tracking technology on the user in a virtual world[8]. The positional tracking is a device allowing to localize a user in a space, in order to retranscribe his position virtually. This technology is mainly used by virtual reality headsets such as the HTC Vive or the Oculus Rift S. Positional tracking can be very useful in certain types of simulations where every part of the human body is solicited. Another haptic tool used in virtual reality to make the simulation even more realistic is the Unlimited hand. It is a Bluetooth bracelet that allows the reproduction of the movements that the user can make with his hand and his arm, all in the virtual scene[9].

This first article[10] question is "Are Virtual reality rehabilitation programs effective?" To answer this question the author, use meta-analysis to cross different studies about VR usage for rehabilitation. The results of this analysis showed that VRR (Virtual reality rehabilitation) programs are overall more effective than basic programs. However, variations were observed between different kind of rehabilitation. For strength and motor rehabilitation the outcomes of VRR programs were statically significant where for balance and gait the results were marginally significant.

The second question is: Why are VR programs effective? For this question, the author did not find an answer yet, but he has strong theories thanks to his observations. The first theory is that VRR programs are better because they increase motivation and excitement. When patients perceive their experiences as unexciting, they often begin to retract from the programs and become less motivated. This lack of motivation may result in less effortful practice of behaviors. Even yet, bored patients may even withdraw from rehabilitation programs completely.

The second theory is that VRR programs are better than basic programs when they show physical fidelity with reality. Patients in rehabilitation programs develop abilities

by practicing behaviors that are dissimilar to typical activities such as moving their hand in a circle or performing finger tapping exercises, instead of performing more typical motor control activities. Many authors have questioned the ability of dissimilar practice behaviors to develop rehabilitation outcomes : "*Only performing certain aspects of the abilities of interest may not sufficiently develop all necessary muscles, and patients may not develop the skill to sequentially link together the different aspects of the abilities*". In addition, the author says that many physical impairments are due to neurological dysfunction, such as stroke, and physical abilities cannot be regained without proper cognitive functioning. Through activating neurological pathways, which can only be done by realistic programs. VRR could be a solution to this problem since nowadays modern technologies able us to recreate similar, if not exact environments to practice realistic behaviors.

The last theory is **cognitive fidelity**. When patients perform their programs, they generally do it in a stimulus-free environment, whereas in reality many cognitive demands may be present. For example, while walking you could be expected to hold a conversation. The author says that many studies showed that cognitive fidelity is an important component for a successful rehabilitation. Researchers have already applied several methods to increase cognitive fidelity like completing verbal math problems, but patients find those programs demanding and stressful. VR could solve this problem too. Researchers *Heiden and Lajoie (2010)* already tested a VR program where patients needed to control their balance in order to progress in a video game. Patients who completed this program significantly improved their ability to respond to an unexpected stimulus.
Despite the strong correlation between the success of the VRR program and these mediation mechanisms, there is still a lack of evidence to support their relationship with the results.

This article of the New York times[11] tells the story of Michael Heinrich. A man who had a motorcycle accident which cause him to lose use of the lower half of his body permanently. Halfway through his rehabilitation program his therapist asked him if he was interested in trying virtual reality therapy. He really liked the virtual reality rehabilitation program, especially on an emotional level where thanks to VR he did things he thought not or no longer possible.

After that, the article retraces an interview with Dr. Brennan M. Spiegel, professor of medicine and public health and director of health services research at Cedars-Sinai Medical Center in Los Angeles, who tells us that the virtues of VR on patient motivation is impressive, and it helps a lot in the rehabilitation process and sometimes prevent them from giving up.

III Methods

The project of rehabilitation with the help of virtual reality, is intended for sports people with a physical handicap. The aim of the project will be to offer several virtual environments adapted to the environment and atmosphere of a sport discipline. Disciplines such as tennis, volleyball, table tennis, badminton, handball, and combat sports can be simulated for their followers. Our project of rehabilitation using virtual reality is intended for all sportsmen wishing to practice their discipline. It could therefore be used as part of the preparation for the Paralympic Games. The virtual environment will integrate an Artificial Intelligence that will train the subject. Indeed, the subject will be in front of the bot which will adapt the difficulty of the training according to the level and the progress of the subject in his rehabilitation. The bot will be explained in more detail later in this article. In this scientific article, we have chosen to present tennis as a sport discipline. We have simulated a tennis court.

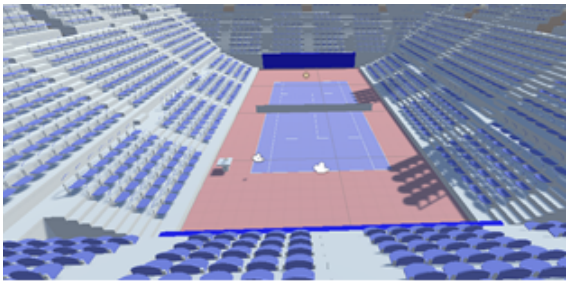

Figure 1: *Tennis court simulated in our prototype*

The environment has been reproduced as close as possible to reality in order to refamiliarize the athlete during his rehabilitation sessions. The athlete will embody an avatar, with the same anthropology as the human body. No gestures or inhuman movements can be performed.

The equipment used for tennis is the virtual reality headset and two controllers. For the experimentation of our project the model used is an Oculus Rift s, however all types of helmets of the same range can be used. The use of equipment known as general public will allow any medical body to appropriate the equipment more simply. For this project a game engine or virtual reality software must be used. In our case Unity3D fits perfectly to this project because it includes several resources and complements linked to our development material. It is also one of the most used software in the world which allows us to have a large enough community to have ideas or useful development methods to solve our problems. For what concerns the development of our virtual world under Unity3D, we will use the libraries made to use an Oculus Rift S, as well as its controllers. The artificial intelligence of this project will be done by the project group, but it will be based on the principle of Open AI which is not available in Unity3D. The use of an artificial intelligence in the context of this project serves to put our user in a situation of confrontation with a virtual person. Moreover, this artificial intelligence will be based on a progressive level of difficulty according to the user. It will be based on a ball exchange system between the 2 players, and its difficulty level will be adapted according to the result of this ball exchange made previously.

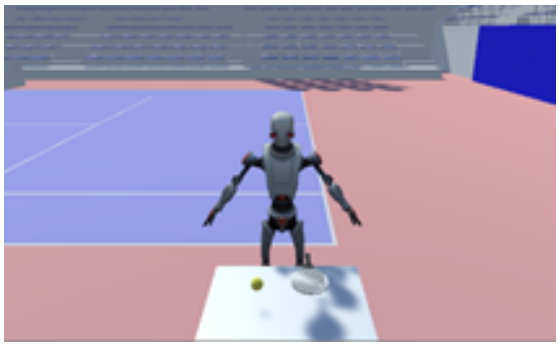

Figure 2: *The prototype Humanoid*

IV Results

In this part of the results we will see how our research on the theme of rehabilitation in virtual reality could be done and what means were put in place to answer the hypotheses of this study.
First of all we had to make a study on the production stroke on the simulation of a sport in virtual reality, we had the choice between several sports with several possible criteria like the possible displacements and movements of the body. We therefore chose the simulation of tennis. For this study we did not just choose a sport on the possibilities of movement but also on the feelings that the user could have with the simulation, that is to say the difference between the real and the virtual and in the field of the sport the feelings can be done mainly by the use of the sporting tools like a racket, a ball or both. We therefore proceeded to create a tennis scene with dimensions that respect the limits of reality. This allows the user to find the same visual sensations that can cause the fact of being on a tennis court. Other sensations must be added like touch. So to provoke the sensation of wearing a tennis racket, we used the joysticks or controllers connected to the virtual reality headset. Indeed using these controllers allows our user to find the physical sensation of wearing a tennis racket. Unfortunately we can only use oculus controllers in our experiments, which cannot provoke all the possible and imaginable sensations with a tennis ball for example. But we can imagine later the use of haptic material like gloves or an exoskeleton to reproduce perfectly the use of the user's hands with also a feeling of weight on the hands. Once the study and design of our prototype of the simulation was completed, we observed the real movements possible in the simulation and established a link with the possibility of rehabilitation. We have therefore drawn up an inventory of possible movements that will allow us to study the behavior of a user under several simulations (service exercise, ball exchange, hitting the ball, etc.).

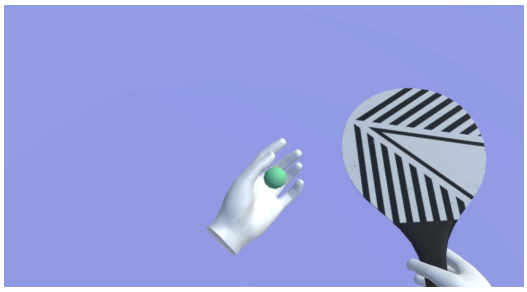

Figure 3

Here we can see (Fig.3) that the user can take in his hands the objects provided, can adjust them as he wishes to have a feeling of ergonomics in his game and the movements he will make in the exercises. Currently we could study the behavior of the user with what our simulation could allow to observe. Unfortunately our simulation has some very good points but also some bad ones and therefore has some areas for improvement. The user can only do simple hitting and throwing exercises with the objects in the simulation so the rehabilitation will be done on simple movements like the use of the arms and wrists which are strongly used in tennis.

Figure 4

After studying the simulation and the experiments carried out, this rehabilitation project is therefore possible because our simulation includes all the sensations possible with tennis, but within the limits of the virtual. We find a potential rehabilitation in the fact of carrying out its exercises with very little risk of injury due to the real world (receiving the ball on the body, having a notion of force on the rackets, moving, etc...). Our simulation still

has a problem concerning the movement of the user because currently he can only move on a small area traced by the limits of the virtual reality helmet, but he can nevertheless move with the controllers.

Figure 5: *The walls; obstacles to virtual reality*

To solve these problems we can imagine later the use of more advanced hardware such as a wireless virtual reality headset, a motion capture suit to take the total body of the user in the virtual world and the use of a very large space to allow the user to find the sensations of size of the real world. Finally, one of the options of our simulation would be to have an AI implementation, to allow a competition or exchange system for the user. And this AI would have an operation based on the performance level of the user to find a feeling of difficulty that might not be present in the simulation of simple exercise.

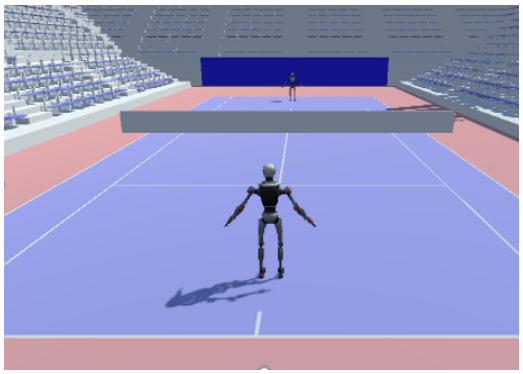

Figure 6: *Rendering of our scene with Unity software*

V Discussion

As we said earlier in this article the goal of our project is to help people with injuries that affect their mobility by improving their rehabilitation experience. To do so, we tried to recreate a VR environment that respects the studies and results pointed out by the article "A meta-analysis and systematic literature review of virtual reality rehabilitation programs"[10]. As we said previously, the article tells us that patients showing a lack of motivation may result in a less rigorous practice and in some case in an abandonment. We also saw that VR and gamification help patients by increasing their motivation and push them to put more efforts in the rehabilitation program. That's why we decided to reproduce a gamified tennis match environment with an AI-driven opponent in VR. Then, the article tells us that physical and cognitive fidelity could improve patient rehabilitation experience by creating strong neurological pathway and by stimulating the patient with realistic stimulus. In order to reproduce this physical and cognitive fidelity we tried to replicate as accurately as possible a tennis match environment and we aim to create an artificial intelligence that will play like a real tennis player while adapting its level to the patients' possibilities in order not to overwork them. Moreover, we are currently studying the possibility to have haptic equipment (body suit, gloves, etc..) to increase physical and

cognitive fidelity by adding the sense of touch. However, our project is still in development and we don't know yet if it will make a real difference for patients. The project still need to be tested.

As said during the presentation of the state of the art, this article[2] deals with the behavior of the glance, more particularly when the subject avoids a collision. The study of this article is comparable to our project since the gaze must be as close as possible to reality. Indeed, the gaze will allow the player to immerse himself more easily in the rehabilitation sessions but also during the resumption of the discipline in a real environment. In the context of a tennis match, like any other sport, visual behavior is important because it guides the player's movement. We then reproduced a virtual environment and a behavior of the virtual player like the study conducted. To reproduce a behavior similar to reality, it was necessary to establish a field of vision and an anthropology of the head as close as possible to reality.

The Inria research laboratory experiments conducted on the use of a multisensory simulator of a wheelchair bringing the patient closer to the real world [1]. We can compare this experience thanks to the common goal they have : to bring the virtual closer to the real in the medical field. The results obtained by their experiments have allowed us to consolidate our own in the sense that our users find themselves performing an activity in a virtual world and then being able to reproduce it safely in the real world. To compare the feeling of using a material as done with the wheelchair, we have replaced the tennis rackets by the controllers of the oculus rift. It can be imagined, therefore, the creation of specific tennis rackets for our prototype with a haptic feedback for a sensation of ball striking which would add better sensations and feedback from the user on our virtual world and what can help him in his rehabilitation.

The technological advances around artificial intelligence are more than actual today. And more particularly when we are interested in what we call neural networks. Indeed, a major feature that would perfect the use of our system would be the use of a unique artificial intelligence for each patient that learns and adapts autonomously by being inspired by human gestures. The recent studies conducted by Ubisoft on this subject are exciting and lead to an infinite number of innovations on a wide range of topics. In our case, the field of pre-selection is health. Some people see in the medical applications of AI the possibility of replacing the doctor, whether to alleviate medical deserts or to screen and guide patients. But the public use of this software without medical supervision raises important ethical questions. The system reduces the relationship with the doctor to a technical act. It leaves the patient to his questions and anxieties. Moreover, there is a real risk that the doctor will abdicate before the machine "which knows better than he does". He may be led to endorse a decision that is not his own and discover afterwards that the machine was wrong. To avoid this pitfall, the doctor, the only one authorized to make a diagnosis, must be able to maintain his autonomy in relation to the machine. He must be able to understand the whys and wherefores of the decisions displayed, and to bypass them if necessary. With this objective in mind, it is necessary to design systems whose operation is transparent, explicit and traceable, and which carry out the specified tasks while respecting explicit constraints. For decision support systems based on learning algorithms, the respect of this conformity is not obvious.

VI Conclusion

To conclude, this project was for the whole team a very first entry in the research field. We believe in the feasibility of this tool and would be delighted to see a summary of this research taken up by other expert researchers.

In the same way that companies are interested in virtual reality to train their staff, this project also accompanies athletes in their training and performance research. A first digital prototype is functional at the time of writing this article, and the only obstacles for the development of this innovation are financial resources and time. Due to the somewhat limited amount of time available for this research, the prototype does not yet include any artificial intelligence implementations. But what would make the team most proud would be without hesitation to see this type of project developed in the medical field in order to bring back the smile to people suffering from the misfortunes of life.

References

[1] L. D. Y. G. B. F. Guillaume Vailland, Fabien Grzeskowiak, "User-centered design of a multisensory power wheelchair simulator: towards training and rehabilitation applications," pp. 1–6, Jun 2019.

[2] J. B. L. H. J. P. Florian Berton, Anne-Hélène Olivier, "Studying gaze - behaviour during collision avoidance with a virtual walker: Influence of the virtual reality setup," pp. 717–725, Mar 2019.

[3] *Compete in Echo Arena – The Competitive and expressive sport of the future*. Ready at Dawn, Jun 2017.

[4] B. C. V. C. P. . C. D. D. F. Q. F. S. H. C. H. R. J. S. G. C. O. J. P. M. P. H. P. d. O. P. J. R. T. S. J. S. J. S. S. S. I. S. J. T. F. W. S. Z. Christopher Berner, Greg Brockman, "Dota 2 with large scale deep reinforcement learning, openai," pp. 1–66, March 2021.

[5] K. Z. (Former Animation Director Ubisoft), *Motion Matching, The Future of Games Animation... Today.* Game Developers Conference, 2016.

[6] M. P. T. P. Daniel Holden, Oussama Kanoun, "Learned motion matching," Jul 2020.

[7] *teslasuit.io/the-suit/*. Tesla.

[8] K. A. M. W. H. P. Timothy TJ Brooks, Huub HC Bakker, "A review of position tracking methods," pp. 54–59, January 2005.

[9] L. Matney, *H2L Launches Their Next-Gen UnlimitedHand VR Haptic Controller*. techcrunch, September 2015.

[10] M. C. Howard, "A meta-analysis and systematic literature review of virtual reality rehabilitation programs," pp. 317–327, 2017.

[11] A. Tugend, *Meet Virtual Reality, Your New Physical Therapist*. New York Times, 2021.