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Positive Impact Game as a Contribution to Movement Rehabilitation

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in

Media Informatics

by

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Registration Number 0726015

to the Faculty of Informatics
at the Vienna University of Technology

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Vienna, 20.03.2013

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Abstract

With the continuous improvements in surgery and the rapid development of bioelectrical interfaces, a new type of prosthesis with a higher quality is developed every year. Although a major step is taken every year, a considerable time gap is between an amputation and the first time the patient can use a fully functional myoelectrical prosthesis. To minimize this gap the IMS[1] created in combination with the Otto-Bock company a virtual exercise tool that helps patients to start the learning process for using the prosthesis in the middle of the healing process. The following thesis builds upon this topic but replaces the exercise environment with a video game environment. With the help of this thesis, the reader should be able to understand the problems after an amputation, to understand the major fields of gamedesign and to distinguish between general game genres. Special attention is payed to the game genre "Positive Impact Game". Its main purpose is the positive feeling/impact the player gets for his or her life while playing the game and afterwards. At the end of this thesis, a full working showcase for a psychological and physiological rehabilitation game is given. Furthermore, future developments on the showcase are discussed.

[1] Interactive Media Systems

Kurzfassung

Durch die stetige Verbesserung der chirurgischen Medizin und der rapiden Weiterentwicklung der Biosignalverarbeitung können von Jahr zu Jahr bessere und qualitativ hochwertigere Prothesen entwickelt werden. Trotz der schnellen Entwicklung liegt immer noch eine beträchtliche Zeitspanne zwischen einer Amputation und dem Anlegen der ersten voll funktionstüchtigen myoelektrischen Prothese. Um diese Zeit zu verkürzen wurde am IMS in Zusammenarbeit mit Otto-Bock eine virtuelle Trainingsumgebung geschaffen welche es PatientInnen schon während dem Heilungsprozess erlaubt die ersten Übungen mit der Prothese zu beginnen. In der folgenden Diplomarbeit wird dieses Thema aufgegriffen und die Übungsumgebung durch ein Spiel ersetzt. Der/die LeserIn soll mit Hilfe dieser Diplomarbeit in der Lage sein, die Probleme die nach einer Amputation entstehen zu verstehen, ein Verständnis von den wichtigsten Bereichen des Gamedesigns bekommen sowie unterschiedlichste Spielegenres kennenlernen. Ein besonderes Augenmerk wurde auf das Spielegenre "Positive Impact Game"gelegt. Der zu Grunde liegende Ansatz dieses Genre ist, wie der Name schon andeutet, dass jedes Spiel einen positiven Einfluss auf den/die SpielerIn hinterlassen soll. Am Ende dieser Diplomarbeit steht ein fertiger Showcase, welcher versucht die Verbindung zwischen psychologischer und physiologischer Rehabilitation herzustellen. Über mögliche Weiterentwicklungen wird unter dem letzten Punkt "Future Work"diskutiert.

Contents

CHAPTER 1

Introduction

1.1 Motivation

The time period between the amputation and the date when a person can start to learn how to use a prosthesis in everyday life is usually relatively long and varies between each person. One of the reasons is the manufacturing process, especially the socket. The socket is the connecting part between the prosthesis and the sump and is individual for every person. Another reason is the healing process. It takes at least six to eight weeks for the healing and as long as the process is not completed, the patient cannot work with a fully functional prosthesis. For an optimal use of these six to eight weeks a virtual environment was created. The environment creates the possibility to start with the rehabilitation process from the first week on to lower the period of time until the patient can use the prosthesis in everyday life.

One of this virtual environments was created in the Institute for Software Technology and Interactive Systems (IMS) and in combination with the company Otto-Bock. The research process has shown that patients have problems with the exercises and graphical interface of the virtual environment. Both, the exercises and the virtual world are very rudimentary.

Since the patients are in a psychological unstable position while working in the virtual environment a positive impact game should be designed and created for this thesis to replace the current virtual world. With the change from an exercise to a positive impact game, the dark and unfriendly environment should be replaced by a friendly and positive environment. It is important that the patient creates a positive relation between him- or herself and the prosthesis.

1.2 Methods

The idea is to build upon or extend the virtual environment created by the IMS. At first, the framework which is divided into IO-Tracker [78], HMD[1] and Unity3D [82] will be tested and

[1] Head Mounted Display

explored for its technical freedom. The next step is to analyze the prosthesis created by Otto-Bock to create a total survey of the current framework.

After the framework is described, interviews with psychologists, physiologists, engineers and game developers are held. With the output of these interviews, the first game design session can start. The game design session should lead to the first game concept. With the help of rapid prototyping, a first showcase which contains a storyline, level design and game mechanics will be created.

Based on the showcase, another round of interviews with psychologists, physiologists, engineers and game developers are held. The outcome should be a description of the mistakes and a proposal for future work.

1.3 State of the Art

In the last decade, computer technologies became more and more a part of new inventions in the field of rehabilitation. With the help of Motion Capture [78] and modern Virtual Reality Frameworks [82] the rehabilitation techniques could be individually adjusted for every patient which puts the quality of rehabilitation to a new level. Projects like the "Chronic Pain Rehabilitation with a Serious Game using Multimodal Input" [59] are extensively using these new technologies.

Since Jane McGonigal became famous with her book "Reality is Broken" [38], the idea of "Positive Impacts Game" has spread. "Positive Impacts Game" is not really a new part of game but a meta description of game. The idea is that a game should have a positive impact on the player and/or on the real world. One type of games that falls into this category of games are serious games which are extensively used in medicine [62] or politics [79].

1.4 Expected Results/Estimated Outcomes

With the switch from exercise to game, it should be much simpler for the patient to learn how to handle the prosthesis. The patient should learn to use the prosthesis in a playful manner. The idea is that the patient sees the prosthesis more like a game controller. Using the controller long enough, no extra energy is necessary for handling the controller anymore. The patient can be fully concentrated on the game.

The estimated outcome is a thesis that everyone who studies computer science can understand. It should include all important information on how to start with the development process of a new rehabilitation game. Furthermore, a showcase should be created in order to demonstrate the potential of a rehabilitation game. Based on those two points, the paper concludes with perspectives of future works.

1.5 Relationship with Media Informatics

One of the main fields of media informatics is to understand the user's needs. Therefore, media informatics utilizes a user center design process to learn and understand users. This type

of research is covered by the courses Interface and Interaction Design, Building Interaction Interfaces, Beyond the Desktop and project-oriented research and design methods. Virtual and augmented realities are covered by the courses Virtual and Augmented Reality and Computergraphic. The knowledge for rapid prototyping and game design is transported by the course Explorative Design. To round up the knowledge "package" that is necessary to understand the topic of the thesis, the course Technology Assessment of Information Technology mediates information about special needs for people who had an accident and/or need other kind of help.

CHAPTER 2

Rehabilitation/(Limb)-Prosthesis

Amputation of a body part is life-changing. Before starting with the game design process, one needs to understand the challenges which occur for an amputee and what stages of rehabilitation follow. The following chapter starts with an overview of two different types of prosthesis. The cosmetic prosthesis which tries to imitate the perfect shape of a human body part but without daily life functions like grasping. And the functional prosthesis which tries to imitate lost mechanical functions like grasping, moving, holding, etc. To get a better understanding of the functional prosthesis and its communication with the amputee, a deeper look is taken on the different control systems: body powered, electrical and bioelectrical. The second part of the chapter is focused on the psychological and physiological rehabilitation. A special focus is given to the stages of rehabilitation. It is important to understand at which stage of the rehabilitation process the rehabilitation game can start and the challenges the patient can handle at a special stage. To understand the risks of virtual reality in combination with HMDs, an introduction of the phenomenon called presence is added.

2.1 Type of Prosthesis

Depending on various conditions/effects/influences like age, money, insurance, type of amputation, every person has to decide what prosthesis fits best. The decision lies between functional and cosmetic restoration [44]. Since industrial design became more influencing in the prosthetic field, functional and cosmetic hybrid prosthesis were produced as well (see Figure 2.3 and 2.2). The following sections will describe the socket, the cosmetic and functional prosthesis, electrical, cable and body powered control systems, as well as the myoelectric and targeted muscle reinnervation bioelectrical interfaces. [35] [69]

The Socket

To connect the prosthesis with the stump a connector, called the socket, must be created individually for every person. The reason for that lies in the different positions where arms were

Figure 2.1: Scott Summit: Artificial limbs [69]

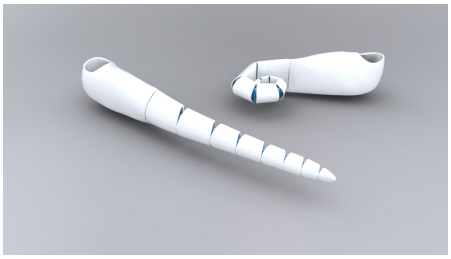

Figure 2.2: Kaylene Kau: Arm prosthesis with an octopus grip [35]

removed and the various shapes and muscle sizes. It is very important that the stock fits perfectly to avoid late damage, like soreness and skin problems caused by mechanical force and produced by the weight of the prosthesis. The socket must be adjusted from time to time, especially during the healing process while the stump is still swollen. After the "perfect" socket is found - according to an interview with Andrei Ninu from Otto-Bock (see Section 5.6), - the prosthesis can theoretically be assembled overnight, because all parts are industrially produced. [83]

Cosmetic Prosthesis

The priority for cosmetic prosthesis is a simple, lightweight and realistic design. Modern cosmetic prosthesis are created on a silicon base and appear as a very life-like cosmetic restoration (see Figure 2.3). However, a cosmetic solution may also provide some functions; first, passive functions like stabilizing a bowl while cooking; second, psychological functions/benefits to raise selfconfidence; third, provide symmetry to prevent future muscular and skeleton problems; and fourth, supports bilateral development for very young patients. [44] According to O'Keeffe "*The overall cosmetic effect is created by a combination of a convincing device, the correct wearing of the prosthesis, and its correct integration into everyday life.*" [44]

Functional Prosthesis

Even though cosmetic restoration looks more natural, a functional restoration feels more natural. Therefore, many patients request a functional restoration. The complexity provided by hand, arm

Figure 2.3: Life-like cosmetic silicon hand. [44]

and shoulder cannot be completely reconstructed. To minimize the gap to a real limb, a series of achievable patterns for the daily use are pre-integrated into the prosthesis. The most important restorations are the joints between shoulder, arm and hand. They provide the ability to put the limp into a natural position.

The shoulder prosthesis is not directly a functional restoration. It is more a cosmetic restoration but provides a higher range of movement, e.g. to make dressing easier for the patient. Furthermore, it provides the necessary function to build upon with more complex arm and hand prosthesis.

The elbow and arm prosthesis replace the ulna and radius. It is a straight forward replacement to raise the movement area for the limp. It is important for the patient to lock the elbow position with a manual or electrical system to provide more degrees of freedom (DoF[1]) for the hand prosthesis.

The hand and wrist prosthesis is the most complex but also most important one. Different types and solutions can be chosen with various complexity levels. One of the cheapest, light weight and manually usable hand prosthesis is the split-hook (see Figure 2.4) prosthesis. It provides a two finger grip in order to manage to hold objects of different complexities like a glass or a plate. Nevertheless, it is rarely used because of its cosmetic compromise and social acceptance.

Controlling Systems

The simplest cable controlled types are voluntary opening and closing prosthesis. For the voluntary opening hand, the patient can only control it when he or she opens the hand and decides how long it should be open. The hand will automatically close after the patient stops the opening process. The opening and closing prosthesis can fully be controlled by the patient but the grip speed and force is pre-configured. The most advanced prosthesis is the electrical control prosthesis. In theory, it is possible to fully control finger speed, force and angle. The problem hereby is the communication system between the body and the prosthesis. This problem will be discussed in section 2.1.

[1] Degrees of Freedom

All in all, controlling systems can be divided into three types. The Body-Powered Control System, the Cable Control System (see Section 2.1) and the Electrical Control System (see Section 2.1). It depends on the patient, the researcher and rehabilitation team, which control type will be used [44].

Figure 2.4: Split-Hook hand prosthesis. [44]

Body-Powered and Cable Control A Cable Control prosthesis is a system where the patient uses only elbow and shoulder movements to open and close the hook. It is a simple but robust and well tested control system. Like seen in figure 2.5, the Bowden Cable[2] is used as a bridge between the hook and the back. With this arrangement, the patient can decide the position of the arm and when to open the hook (see Figure 2.6). To provide a more cosmetic realistic prosthesis, the hook can be replaced by a system hand [46] and yet the mechanics remain the same. [87] [44]

Electrical Control Electrical Controlled Prosthesis can be divided into two main parts: first the mechanics and second, the control unit. The idea of electrical control prosthesis is to simulate a real human hand/arm [80]. During the last years, these prostheses have made great progresses. Examples can be seen at the i-LIMB [80] or DMC[3] [47] from Otto-Bock.

[2]The Bowden Cable was originally introduced by the Raleigh Bicycle Company as a bicycle actor in the late nineteenth century [87].

[3]Dynamic Mode Control

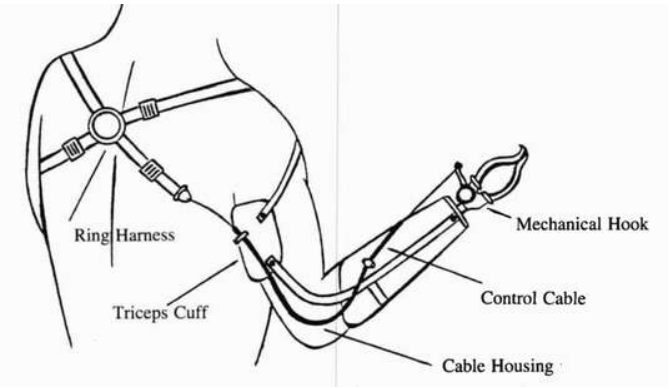

Figure 2.5: Cable controlled prosthesis [53]

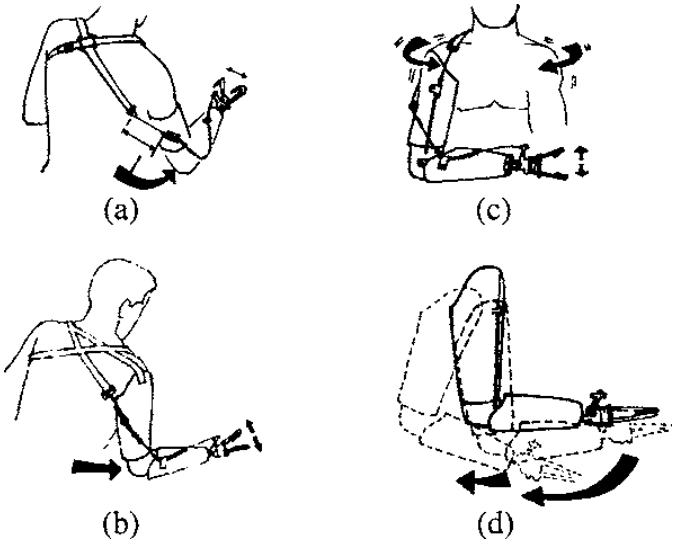

Figure 2.6: Schematic showing of a cable controlled prosthesis [87]

The first part of the prosthesis is the socket connector. It is unique for every patient and provides the connection between the prosthesis and the socket. The second part is the arm. It is divided into the wrist rotator, the battery and the electronics (see Figure 2.7). The wrist rotator has an interface to connect the hand with, and is controlled by the arm electronics. To control the prosthesis, the electronics provide a bus system. This bus is connected with a micro controller, a wrist rotator and a communication device which is mounted somewhere on the human body. [80]

The hand and fingers are the most complex mechanical parts of the prosthesis. Every finger is assembled by high complex mechanical parts like plastic bones, joints, gearbox and motor [11, p. 3]. But the "real" complexity lies in the synchronization and speed between the fingers.

Because of the bioelectrical interfaces limitations (see Section 2.1) it is not efficient to move every finger independently. Therefore, often used grip patterns are pre-stored [11] [84]. The

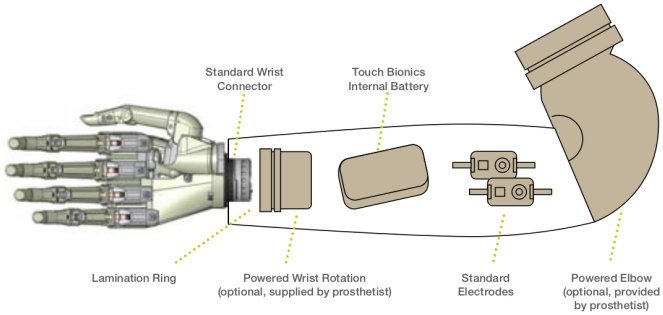

Figure 2.7: i-LIMB arm parts [80]

benefits are a fast individual grip and a simple communication interface with the human's communication device.

Bioelectrical Interfaces

While the mechanics of modern prosthesis (like i-LIMB [80] or DMC [47]) have made a big progress over the last years, a lot of research has to be done in communication between the prosthesis and human body. The goal is to measure human's bioelectrical signals, which are based on the shooting of neurons. [31, p. 10]

The neuron is the fundamental base of the sensory system, movement system, central nervous system and peripheral nervous system. To activate any of those systems, the neuron "shoots" an electrical signal. To know what region in the body is activated, only the electrical differences in the relevant surrounding must be measured. The difference is based on Na^+ and K^+-Ions in the neuron. If the neuron is inactive (Resting Potential), the difference between the Na^+ and K^+-Ions is 50-100 mV (see Figure 2.9). As soon as a synapse starts to influence the neuron, the potential between the Na^+ and K^+-Ions changes. In the center of the neuron is the cellular membrane which allows only Na^+ and K^+-Ions to cross. If the Na^+ and K^+-Ions cross a threshold, the membrane releases all Na^+ and K^+-Ions which can be seen in the falling phase of figure 2.9. After a "shooting", the neuron has to recover the Na^+ and K^+-Ions. In this phase, the neuron cannot shoot a second time. [31, p. 12]

Myoelectric Interface The myoelectric interface is a wide spread and robust biosignal communication interface. The underlying technology is called Electromyography [EMG[4]]. It uses two or more electrodes on the skin to measure a muscular contraction which can be seen in figure 2.10. To control a prosthesis, the electrodes are placed on upper and/or lower limb muscles. By contracting and extracting the muscles, a signal processor interprets the signals and sends a control signal to the prosthesis. Depending on the setting, the complexity of the prosthesis and the number of electrodes, the patient can move the prosthesis in ways such as opening/closing, moving the thumb or changing the angle of the wrist. [31, p. 19]

[4]Electromyography

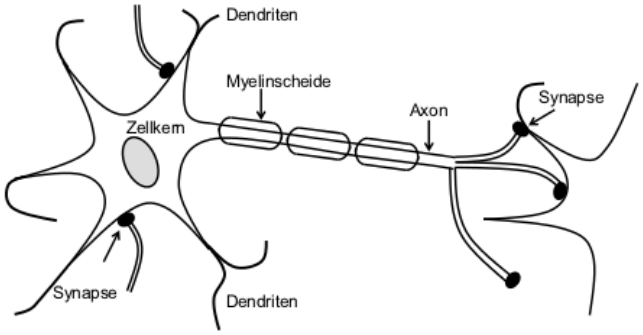

Figure 2.8: Elements of a cell [31]

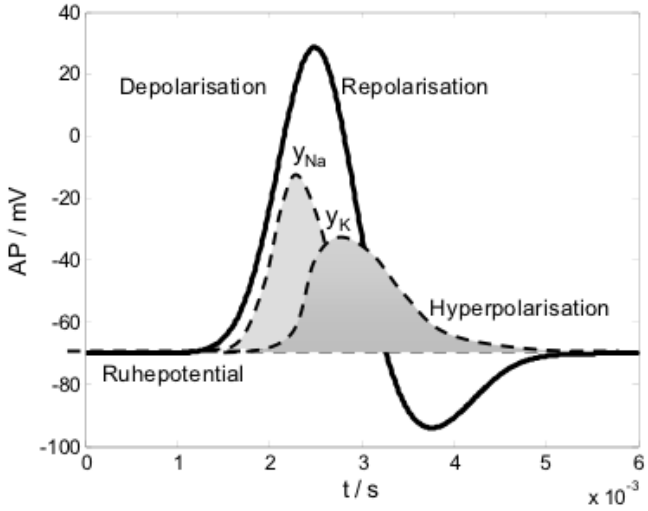

Figure 2.9: Biosignal curve of a shooting cell [31]

Targeted Muscle Reinnervation Targeted Muscle Reinnervation [TRM[5]] is a special surgical technique where the original nerves from arm or hand are transferred to another part of the body. This part can be the chest and/or shoulder. The idea behind TRM is that the patient can use its normal habits to move the hand/arm. To measure the signals on the alternative muscle site, an EMG based pattern recognition algorithm is used. The benefits of this technique are more complex movements with the prosthesis and a lower learning curve. [29] [71]

2.2 Physiological and Psychological Rehabilitation

The loss of a limb is always a tragedy for a person whether it is caused by an accident or not. Therefore, the rehabilitation process can never be divided into only physiological and only psy-

[5]Targeted Muscle Reinnervation

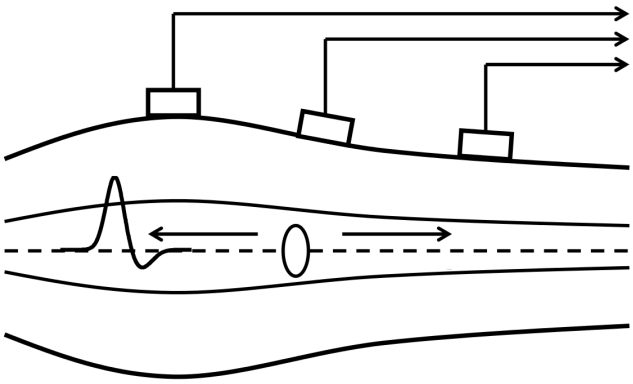

Figure 2.10: Three electrodes measure the time difference on one signal. [31]

chological rehabilitation. It must be seen as a process specifically designed for every patient. Nevertheless, the path from the amputation until a full functional prosthesis can be divided into amputation, healing process, interims restoration, rehabilitation and finally the functional prosthesis. The final goals of the rehabilitation are: First, the patient should stay as independent as possible. Second, the patient should become independent from health care. Third, the rehabilitation should make the carrying easier. Fourth, mobilize the limb for a future prosthesis. Finally, adapting and adjusting to prosthesis. The goals for the therapy are: "Creating" the possibilities to use the prosthesis on a daily base; practice/train compensation techniques; harden and strengthen the stump and muscle; train the muscle contracture and joint mobility; group therapy; adjust the private home and practice Activities of Daily Living ADL[6] [28] [14] [63].

Several physiological reasons like infection, deformation, PAOD[7], bone tumor and trauma are known for an amputation. The author of this thesis is mainly interested in amputations after a trauma, because the majority of all amputations are caused by accidents [3] [2] [1]. In this scenario, the patient wakes up after the amputation and realizes its loss. The American Heritage Stedman's Medical Dictionary defines trauma as followed: "*A serious bodily injury or shock, as from violence or an accident. [76]*".

After the amputation the patient gets a bandage around the stump. The goal is to get the perfect form for the prosthesis. It takes between 6-8 weeks until the stump is in a shape for using daily-life prosthesis like in section 2.1. Only a full recovered stump can profit from this type of prosthesis.

The interim restoration takes place in the first period of 14-21 days after the amputation. At this stage, the wound heals and hardens. At that point, the patient can start to work with an interim prosthesis. The healing process can be influenced by the health state, age and the way the patient practices with the prosthesis. It is very important that the patient and therapist take care of the healing process and the burden on the wound. As sooner as the wound heals the sooner the patient can use and practice with a real prosthesis.

[6] Activities of Daily Diving

[7] Peripheral Artery Occlusive Disease

If the patient's hand was fully functional before the amputation he or she still has a fully functional two arm coordination. Furthermore, the patient is in a trauma and in shock. This stage can, in theory, be used to push the patient in rehabilitation without giving time to think about her or his situation and giving the chance to fall into a depression. According to an interview with Anna Felnhofer and Oswald Kothgassner (see Section 5.6), the assumption to push a patient into rehabilitation before he or she falls into a depression can be used in many cases but must not be generalized. They said only the therapist knows the patient good enough to give a correct answer .

2.3 Supporting Psychological Health with Virtual Reality

Virtual Reality VR[8] has been shown as an effective therapy for psychological healthcare. Especially young people like VR in therapy. That is because computer games are part of their lifestyle and young people are more interested to engage in psychotherapeutic because it involves technology and computer games.

A distinctive benefit only VR adds to the therapy is the simultaneous experience by the therapist and the client. This gives the therapist the possibility to adjust the stressors gradually and consistently. Furthermore, stressors can also be presented in a progressive and measured manner. Another advantage of VR is the limited risk for further traumatization by setting the client into an uncontrolled environment. Sometimes, clients believe they are physically in the VR. In this case, the VR must be designed to be a safe, gradually changing environment, to ensure that the client is not exposed to an environment he or she cannot handle at his or her current psychological condition. Section 2.4 will discuss this subject more precisely.

A very high success rate between 66 and 90 percent in combination with VR can be seen with PTSD[9] patients, especially collision related PTSD [86]. Research has shown that a higher level of immersion, which leads to a more emotional and realistic therapy, is given by HMDs instead of normal screens. Also relaxation exercises paired with VR show a faster reduction of the intensity of chronic pain. The VR technology is also used for patients who cannot remember the reason for their PTSD. In that case, the scenario can be virtually recreated to refresh one's imagination. [64] [67]

2.4 Presence: What people feel in a Virtual Reality

> "*If you are there and what appears to be happening is really happening, then this is happening to you! Hence you are likely to respond as if it were real. [65]"*

Presence is in the context of Virtual Reality seen as the feeling or experience of being in the VR environment [85]. Witmer and Singer define presence as "*the subjective experience of being in one place or environment, even when one is physically situated in another [89, p. 225]"*. The way presence is experienced is divided into two factors. First, the physical or

[8] Virtual Reality

[9] Post-traumatic stress disorder

perceptual dimension that describes the sense of being physically located in the virtual space. Second, the social dimension that describes the perceived possibility of interaction and existence of others [56].

For game designers it is important to understand that "*plausibility of events is more important than the exact photo-duplication of reality [8]"*. In a Virtual Reality are three variables which affect the presence; the technology variables, the user variables, and the interaction variables [85].

Technology Variables

> "*It is not the fidelity to the real model (the world) that makes the synthetic environment looking and feeling real, but the fidelity to the perceptual conditions involved in the mental construction of perceived objects. This fidelity could be attained by taking into account the specific sensorimotor determinants of visual perception, or some higher level features such as object files. The believability of synthetic objects depends on the adequacy of the reproduction of the relevant aspects of the perceptual mechanism involved, and not on the realism of the reproduction of the stimulus. [8, p. 435]"*

A person may experience the virtual reality as real, even if it is not photo realistic. Discordant elements, like a wrong flag or the color of a fruit, are more distracting than a square for the flag or a sphere for the apple. People can easier fill a gap when something is missing than removing discordant elements. It creates the feeling of "something is wrong". An experiment with Israeli soldiers showed that the soldiers got disturbed by a wrong uniform, weapon or vehicle but not by the undetailed environment. Also the sensorial depth for detail, movement, stereoscope, etc. has a huge impact in the presence. The world must feel real, even though the field of view and illumination have no impact. They both can be seen like a person who experiences cataract. The illumination is not the same anymore; still the world appears as the same. Furthermore, a full immersive HMD display has a higher impact on the presence than a normal screen [88] [85] [8].

User Variables

To experience the presence in a VR, not just the technological variable must be correct but also the user variables. Not every user is able to feel present in a VR. This is influenced by personality, cognitive abilities, level of anxiety, ethnicity or gender [85]. Other variables, like reactivity to reward and punishment or sensation seeking, are not influencing the presence [33]. The therapist should test every patient if he or she is able to feel present in a VR.

Wallach et al. describe six variables which have clear associations with presence [85]. First, the empathy of a person: "*Direct identification with, understanding of, and vicarious experience of another person's situation, feelings, and motives. [75]"*. Second, the imagination of a person: "*The faculty or action of producing ideas, especially mental images of what is not present or has not been experienced [9]"*. Third, the immersive tendencies of a person: "*Is a theoretical construct that relates to the tendency to behave playfully and to become involved in a continuous stream of stimuli [85]"*. Fourth, the dissociation tendencies of a person: "*Separation of a group*

of related psychological activities into autonomously functioning units, as in the generation of multiple personalities [74]". Fifth, the locus of control of a person: "*Refers to the degree to which subjects feel they control events in their own lives, or that such events are influenced by external, forces, chance or luck [55]"*. Finally, the cognitive style of a person: "*Is a unique way in which unconscious mental processes are used in approaching and/or accomplishing cognitive task [58]"* and in processing and reasoning information [56].

Interaction Variables

The interaction variables describe the degree in which a person is allowed to influence the virtual environment and content [68] [85]. The lower the delay of interaction directly or indirectly with the environment the better is the presence. When players can actively control the environment, they report a higher level of presence than if they passively experienced it [49]. Also the realistic interaction, body movements and physic are important. For example, an apple falls off a tree but far too slow or too fast. The players imminently feel the difference. It is important for the players to have the possibility of acting and more importantly the possibility of successfully acting. [22]

2.5 Conclusion

To create a virtual or non-virtual rehabilitation game it is necessary to know exactly the rehabilitation stage of the patient. If this is not possible the game must be created in a way that the therapist can set the degree of difficulty and or the game changes its difficulty according to patient's current state. Especially for rehabilitation, it is hard to create a game which fits all types of rehabilitation and amputation. Therefore, it is better to focus on one special area in combination with amputees, patients and developers. If the project requires developing a virtual reality game it is important to understand the power of visual impressions. The wrong visual impressions can lead to a bigger harm or a fallback in the rehabilitation stage. This can become even worse when using a fully immersive technology like HMD.

CHAPTER 3

Play the Game

"The goal of successful game design is the creation of meaningful play. [57, p. 49]"

Video games are a rising phenomenon in media industry for the last 40 years. From early games like Pong to photo realistic games, like Watch Dogs (see Figure 3.1), video games can simulate an uncountable variety of virtual worlds. Since the early days, they are used in the military, health, education etc. field. With the power and affordability of computers more and more advanced video games were created. However, the reason for the rapid grow does not only lie in the power and price of video games but it is located in the game play. The variety of game plays from racing game over shooter to casual game makes it fascinating for young and old people to play.

Figure 3.1: Pong release year 1972 and Watch Dogs release year 2013

To create a video game one should first understand the difference of play and game by looking at the following phrases: Dogs are chasing in the garden. Children are singing a song. Kids are rolling around on the grass. Students are playing hide and seek. Managers are playing World of Warcraft. Friends are playing cards. All of those activities can be considered as play, but not all for example "Kids are rolling around on the grass", can be seen as a game. For instance: the business game, the art game, the political game. All of those can be considered

as games but not all can be seen as a play. The previous two examples show that in some cases play is a subset of game and in other cases game is a subset of play (see Figure 3.2).

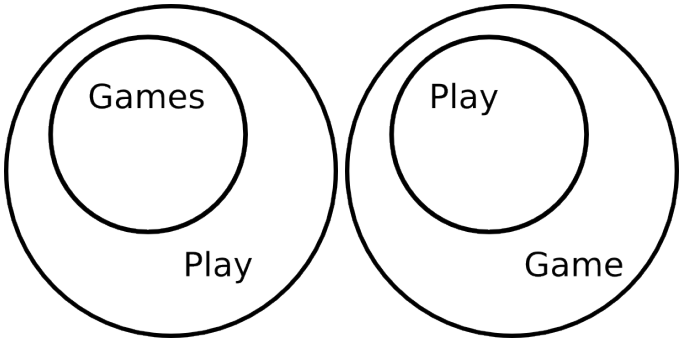

Figure 3.2: Games as a subset of Play and Play as a subset of Game. [57, p. 84]

The second major part is motivation. Video games are so successful because they have a motivating effect on the player. A good video game wants to get played over and over again. The field of motivation is divided into two basic types. The intrinsic and extrinsic motivation whereby a good video game includes both types of motivation. The intrinsic motivation comes from the player itself. It can be seen as the satisfaction the player has while walking from one point to another or in other words: the way is the goal. The extrinsic motivation, in contrast, is the motivation that comes from the outside of the player. It can be an achievement, money or being the first in a race. It can be seen as the satisfaction of the player at the end of the game, after he or she achieved the goal or in other words: the goal is the goal.

3.1 Game

> " *A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome. [57, p. 93]"*

The definition of game has the same complexity as the definition of play but there is one major difference. Where play is older than culture, game is created/defined by humans and therefore a part of culture. Even though, game is defined/created by humans, there is no clear definition of game. Many definitions exist, so it might be helpful to consider the interpretations of Salen and Zimmerman [57, p. 85] who compared eight definitions of game.

They found two major aspects: Rules and Goals; and formalized six primary ideas that every game has (at least most of them): system, players, artificial, conflict, rules and quantifiable-outcome.

System The concept of a system is introduces in section 3.2. Systems are fundamental to the approach to games.

Players A game is something that one or more participants actively play. Players interact with the system of a game in order to experience the play of the game.

Artificial Games maintain a boundary from so-called "real life" in both time and space. Although games obviously occur within the real world, artificiality is one of their defining features.

Conflict All games embody a contest of powers. The contest can take many forms, from cooperation to competition, from solo conflict with a game system to multiplayer social conflict. Conflict is central to games.

Rules Rules are a crucial part of games. They provide the structure out of which play emerges, by delimiting what the player can and cannot do.

Quantifiable outcome Games have a quantifiable goal or outcome. At the conclusion of a game, a player has either won or lost or received some kind of numerical score. A quantifiable outcome is what usually distinguishes a game from less formal play activities.

3.2 System

> "*A system is a set of things that affect one another within an environment to form a larger pattern that is different from any of the individual parts. [57, p. 64]"*

One of the six formalizing ideas for a game is the system. Taking a look at the concept of a system, one can also describe every game as a system. Salen and Zimmerman describe a system as "*A group of interacting, interrelated, or interdependent elements forming a complex whole. [57, p. 64]"* These are some examples of systems one might know; political systems, physiological system, a group like an NGO, organized methods, transporting system and many more. Learning from these systems is that all of them depend on smaller/simpler parts and form together a more complex system. Taking a look at the concept of a game, it is clear that a game must be a system. As an example, a traditional volleyball game shall be examined to explore how all parts interact with each other (see Figure 3.3).

The objects in the game are; the player, the ball, the net, the playground, the teams A/B. The rules add attributes to every object. For instance, the ball is not allowed to fall on the floor. Internal relationships between the object exist. Another example, the ball is in field A, Team A gets into an offense position and Team B gets into a defense position. The game itself is played in a special environment, like a hall or an open air place surrounded by a cheering audience.

The previous example shows that a game/a system consists of objects, attributes, internal relationships and an environment. Nevertheless, looking at a volleyball club, every game can be seen as part of the system or the volleyball league in a country, every club can be seen as part of the system. What can be learned from all of those examples is, that first, every system consists of many more simple parts as the system itself, and second, each system integrates previous systems, E.g. Biological-System -> A Human -> Social Systems (Family, Community, Country) [57, p. 64]

3.3 Magic circle

> "*Is a finite space with infinite possibility. [57, p. 107]"*

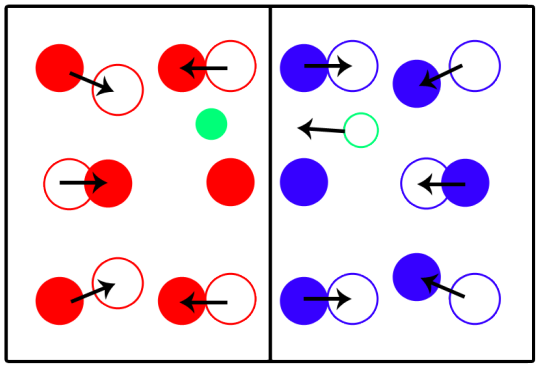

Figure 3.3: Changing the ball means changing the whole system.

The magic circle can be seen as a virtual frame around a game. As soon as a player steps into this circle the rules of the real world change into the game world. This phenomenon can simply be observed by watching children playing with their dolls. They know it is just a doll but as soon as they start playing with the doll, they pretend it is a real person/baby and play unreal things. But it is important to understand that this happens only in the magic circle. The child can easily step out of the circle by leaving the doll on the floor and move away.

The magic circle introduces not only a "new world/space" with new rules, it introduces also a new feeling of time. Studies show that people who play games (being in a flow) have no feeling for time. If a person is really "into" the game, he or she will lose its ability to measure/feel time. This effect is also known as "flow" [12].

Through the doll example it is "easy" to know when a person is in the magic circle but the boundaries between the real world and the magic circle are unclear. How unclear these boundaries are depends on the game. If a person plays a card game it is obvious if he or she is in or out the magic circle. But if this person is in the break between a soccer game, it is not clear if this person is still in the magic circle or not. For some games like monopoly, the magic circle can easily be crossed by leaving the game. But this action would disrupt other players. [57, p. 105]

By creating defined boundaries around a game, the player has secure rules he or she can rely on. Every player knows exactly what is allowed and what is not allowed, or what is possible and what is impossible. Furthermore, if the player crosses the circle he or she can learn out of this "mistake" and get back into the game. This is a very powerful difference between the real world and the magic circle. The boundaries are not only rules to be secured by, they also force the player to stay under the rule. If we look at the game golf, the goal is to "bring" a ball into one defined hole. The easiest and logical way would probably be to take the ball into one hand and put it in the hole. Instead of using hands, the rule says the players have to use a club to shoot the ball into the hole. It sounds illogical but this rule makes it possible that the game lasts for a while and players can compete with other players or with him or herself. It forces the player to adapt to the "new world rules" and the goal changes from getting the ball into a hole rather into enhancing the ability to handle the golf club. [57, p. 105]

3.4 Play

> "*Engage in activity for enjoyment and recreation rather than a serious or practical purpose [50]"*

Fact is, children and animals are all playing. No one orders them to play, they do it on their own. One might say, play is an essential part of animal's nature. For instance, first, two playing dogs stay at the rule not to bite. Second, they pretend to be really angry. The outcome is a higher experience, fun and enjoyment. With all the different perspectives of play, it is clear that play must have a significant function for animals. It seems to be an instinct [30, p. 7].

> "*Nature, so our reasoning mind tells us, could just as easily have given her children all those useful functions of discharging superabundant energy, of relaxing after exertion, of training for the demands of life, of compensating for unfulfilled longings, etc., in the form of purely mechanical exercises and reactions. But no, she gave us play, with its tension, its mirth, and its fun. [30, p. 9]"*

As mentioned above, play is a "thing" on its own. It is not a part of civilization because it happened before civilization. But play has a social function. With "play", subjects can explore objects not worrying about making mistakes.

Colloquially, we say play is the opposite of seriousness. In fact, play is non-seriousness. Play can include serious parts but the main purpose can never be seriousness. The main characteristics of play distinguish play and seriousness. First, play is a voluntary and therefore free activity. Second, play is never ordinary or real life. Actually, it is more a step out of the real world into a new world surrounded by the magic circle (see Section 3.3). The following example demonstrates how early children understand that play is not "real" and/or in an alternative reality. [30, p. 14]

> "*A man found his four-year-old son sitting at the front of a row of chairs, playing "trains". As he hugged him the boy said: "Don't kiss the engine, Daddy, or the carriages won't think it's real. [30, p. 14]"*

A more detailed definition between serious and positive impact is described in sections 4.1 and 4.2.

3.5 Meaningful Play

> "*Creating meaningful play is the goal of successful game design. [57, p. 50]"*

> "*Every action a player takes is woven into the larger fabric of the overall game experience: this is how the play of a game becomes truly meaningful. [57, p. 51, par. 6]"*

The game of chess is an intellectual duel, sports like soccer require improvisational knowledge and hide and seek challenges the observation abilities. All of these games have in common that the players interact with the game to play. For every turn, the player makes a choice and takes an action. Every turn or action means something for the game. It changes the situation in the game and on all other objects in the game (see Section [3.2). The importance for the game designer is to make every move a player can make as meaningful as possible. With the words of Sales and Zimmerman: "*Creating meaningful play is the goal of successful game design. [57, p. 50]"*

Sales and Zimmerman suggest two types of understanding for meaningful play. First, every action that a player can take leads to a new outcome. Therefore, a meaningful play is called descriptive because it describes the actions and stages in the game. Second, the action is discernible and integrated in the larger context of the game. [57, p. 50]

3.6 Motivation

> "*If you want to build a ship, don't drum up people together to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea" [26]"*

Motivation encourages people to start a project, work, etc. But motivation cannot directly be observed by others. It can only be observed by watching how people work on a project. Therefore, motivation is a state in which a person can be in. To indicate if a person is in the state of motivation, one must have a goal, be exerted and have the possibility to work without any distraction [54].

Motivation is especially interesting in this thesis because it aims at patients to stay motivated during their rehabilitation. Because of the situation in rehabilitation - similar exercises every day - the patients tend to be demotivated. To understand how to motivate patients, one must first understand motivation itself.

According to modern literature [13], motivation is divided into intrinsic and extrinsic. Extrinsic (see Section 3.6) describes motivation coming from the "outside" and intrinsic (see Section 3.6) describes motivation coming from the "inside" of a person. Every type is then divided into subtypes which are shown in figure 3.4.

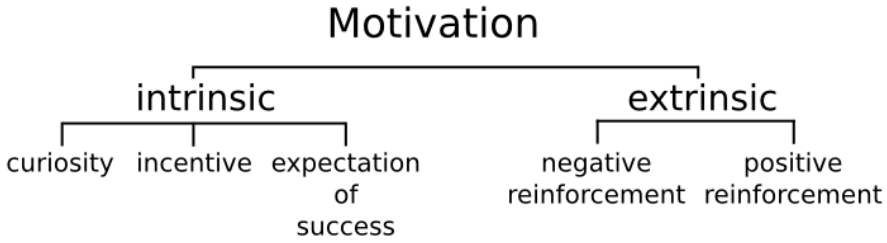

Figure 3.4: Types of motivation with its subtypes. [13]

Extrinsic

In school, a good grade is the motivation. In work, money is the motivation. In sport, winning is the motivation. All of those types can be seen as extrinsic motivations. Most of the time, the "western" society uses extrinsic motivation. "Probably" because it is the easiest way to scale up motivation to some hundred people. It also provides pleasure that the task itself cannot provide. [4]

The problem with extrinsic motivation is people stop doing interesting, good things if they do not see/get revenue as soon as they are done. They also stop improving if they reach the point of getting revenue. For example: Tell a worker to implement a function and he or she gets a hundred Euros. He or she will implement this function in the fastest and most careless way because it is just about the functionality. Another example: Give kids some candy if they do their homework. In this case, the homework will not be good or exact but it is done. [13]

Extrinsic motivation is divided into positive reinforcement (reward) and negative reinforcement (compulsion). The negative reinforcement is a way to punish a person. For example, a child has bad grades in math. The parents say: You must get better in math or summer camp will be canceled this year. On the other hand, positive reinforcement creates a reward if a task was done. Both types and extrinsic motivation in general can be seen as the "bad" type of motivation. This type of motivation from the outside does not hold very long and is not extending itself. [13]

Examples

> "*Every afternoon the neighborhood children played baseball in the lot. The old man, annoyed by all the yelling and commotion, developed a plan to stop the children from using the lot. One day while they were playing, he told them that he would pay each of them $5 every day they came to play in the lot. They thought he was a little nuts but were thrilled to be paid to do something they did anyway. After a few days, he told them he couldn't afford to pay the $5 but still wanted them to play in the lot, and asked if they would accept $1. They grumbled a little but agreed to take the $1. A few days more passed and he approached them with an apology telling them that he wouldn't be able to pay them anymore but hoped that they would still play in the lot anyway. The children responded by refusing to play in the "stinking" lot if he wasn't going to pay them. [19]*"

> "*Only good grades get a sticker. From the beginning children are rewarded for good work. Lack of a sticker is a disappointment, so they learn to work for it. [66]*"

> "*Token motivation is practiced in many different forms. One example is earning "school money" for good behavior, academic or social. The money is used to purchase items, or for participation in a special event. [66]*"

> "*Grades earn promotions. The ultimate goal is a career and successful life. Students are held back or do not graduate if they do not pass the tests. [66]*"

"*If students wait for grades they are no longer motivators and loose[sic] their impact. To this end, most school post grades on the Internet for students and parents to access. [66]"*

"*No Pass, No Play is a state wide initiative in Texas. If you do not pass, you will not participate in extracurricular activities such as band, cheerleading, choir, or sports. [66]"*

"*Programs are created to give instant gratification. Students are praised and sometimes given rewards. [66]"*

Intrinsic

Compared to extrinsic motivation, "*the intrinsic motivation comes from the pleasure one gets from the task itself or from the sense of satisfaction in completing or even working on a task [5]"*. This type of motivation is also called "good" type of motivation. For instance, if a child works on any project because he/she is interested in it, he/she will improve it as many times as it is possible. Therefore, the quality of the project is getting better and better. Would one give the child money to make the same project, the child would only create the project but without perfection. This example should demonstrate a major difference between intrinsic and extrinsic motivation and it is important to create games and tools to promote intrinsic motivation.

Intrinsic motivation is divided into curiosity (cognitive [1]), incentive (emotional) and expectation of success (probability) [13]. To be intrinsic motivated, all of those three types are needed. Depending on the person and the project every type has a different satisfaction level.

Like many animals, humans are curious from their first day on and try to discover their surroundings. To start the curiosity "process" the new element (object, movement, etc.) must create a perfect contrast between elements already known and the unknown elements. Is the new element too close to a familiar one, it will not start the curiosity "process". Is the new element too complex, it will also not start the curiosity "process". For example: a child learned how to calculate 1+3. If it sees 1-3 it may start to become curious about the "-" and wants to find out more. If it sees 2+2 it may not start to become curious because it is too close to the calculation it already knows. And if it sees $\sqrt[n]{1 + x + x^2 + x^3 + \dots}$ it may not start to become curious because it is too far from calculations it already knows. To use this knowledge in a game, players need to be given simple elements at the beginning of the game and start to create and show more and more complex elements. The complexity lies in the step from one new element to the next new element. [13]

In comparison to the curiosity, incentives are driven by feeling. Every person has resting needs. Those needs can be triggered by incentives. As soon as a need is triggered, a person gets motivated and tries to satisfy this need. For example, one searches the internet looking for some research papers. One gets a little hungry but is not realizing it because of the search process. As soon as one sees a pizza advertisement, one gets hungry and wants to satisfy this need. To use this knowledge in a game, a need in the game should be created. For instance, the player

[1] relationship with the surrounding

uses magic serum for some special magic trick, but one is currently working on a quest and is not concentrated on its serum level. As soon as one walks by a serum lake, one wants to collect serum from the lake. [13]

To start the motivation process, one must have an expectation of success. Is the problem very interesting but too hard to understand, ones expectations of success are too low to start the motivation process. For example, a child wants to become an astronaut and fly to Mars. As soon as it realizes it must be older than 18, needs a university degree and has to wait until someone has enough money to send it to the Mars, the expectation of success is decreasing and the child will probably never start trying to become an astronaut. To use this knowledge in a game, the player must be given a challenge one can solve. If one looks at a problem and one has no expectation of success, one will probably never start trying to solve the problem and starts to get frustrated.

3.7 Conclusion

To create a fun and interesting game it is important that all actions a player makes are meaningful. The player must get the feeling that his or her actions can change the outcome of the game. To make the player stay with the game, it must be motivating. Some games focus more on extrinsic motivation, others on intrinsic but most of them include both. For instance, Geocaching is a game where the player must find a hidden box in a public area. The extrinsic motivation is to find the box, but the intrinsic motivation is to enjoy the nature and to have a nice time with friends while looking for the box.

Especially in combination with games which include the real world or reflect parts of the real world, for example rehabilitation games, it is important to carefully create game rules to create a magic circle around the player. The magic circle creates a boundary in which the player can do things he or she cannot do in the real world. It creates a secure area where mistakes are allowed and/or necessary to play the game.

CHAPTER 4

Positive Impact Games and more

Video games and games in general can be divided into groups or types. With the complexity of the game industry new game types where born. In many times it cannot simply be distinguished between one and another because most of modern games combine elements of different game types. Since technologies like smartphones were spreading and game engines like Unity3D[1] became affordable for one man/woman companies a new type of game industry, the indie community was introduced and brought new energy and ideas in the scene.

For this thesis, a video game showcase was created which combines five different game types. First, the "Serious Game". Serious games are games where a special focus is set on a serious or learning topic which influences directly the game mechanics. Most of the time, serious games are in relation to a real world event or topic. Second the "Art Game". Art games compared to the other game types cannot be defined that easily. Like all types of art it is often a view of perspectives if a game is art or not. Nevertheless, in this case art is more about the feeling one has while playing than a description of the game mechanics. Third, the "Exergame". Exergames are games where the player needs to exercise and move in front of the screen to accomplish the challenge. The goal is to make people move. Fourth, "Rehabilitation Games". Like the name suggests, rehabilitation games are focused on the physiological or psychological rehabilitation. The last game type is "Positive Impact Game". Positive impact games must be distinguished between all other game types. The reason for that is that positive impact games are a form of a meta game. It does not try to influence the game mechanics or the game itself, it tries to influence the player by teaching or showing him or her information he or she can use to make the (real) world a better place.

4.1 Positive Impact Games

The term "positive impact games" gained publicity by a game developer named Jane McGonigal. In her book "Reality is Broken", she describes how games can and should change the way

[1] http://unity3d.com/

people think of the "real" world and how this type of thinking can help us solve real world problems [38]. During the last years, the academic discussion was dominated by the question what the difference between positive impact games and serious games is [32, p. 3]. Nowadays the definition of positive impact game has become clearer.

Positive impact game is not a special category of game. It is a meta-category. It is a way of thinking; an idea of how to give every game a positive impact on the real world. Dimitri Salcedo says positive impact games give greater meaning to all games [32]. In other words: positive impact games do not interfere with the game mechanics like serious games, positive impact games enhance the core element of the game by giving it a "real" meaning [32].

For example, the game Portal (see Figure 4.1) can be seen as positive impact game. The core mechanic of the game is to use portals and real physics to solve world puzzles. But the positive impact is that the player gets a better feeling for physics and he or she gets an imagination of how the future relationship between humans and artificial intelligence could be. The master computer of the game is called GLaDOS[2] and it uses humans to learn how to think logically and solve problems by observing them.

Figure 4.1: The physics puzzle game portal

Another example is YourTurn [51]. The core mechanics of the game is to create a YouTube video mash-up between two anonymous players. Every player can add a video snippet as an answer to the other player. At the end, a video mash-up is created. But not only a new video was created, the anonymity drops and the players see each other. The result is that the walls between two people from different social backgrounds start to break down. The game helps people to leave their own secure circle of culture and friends to meet new friends. [51]

It can be asked why there are fewer attempts to solve these social gaps within the real world. Jane McGonigal writes that an enormous amount of people [16] starts to escape into the virtual

[2]Genetic Lifeform and Disk Operating System

world. That is the reason why a computer game is used to fill this social gap.

> "*The truth is this: in today's society, computer and video games are fulfilling genuine human needs that the real world is currently unable to satisfy. Games are providing rewards that reality is not. They are teaching and inspiring and engaging us in ways that reality is not. They are bringing us together in ways that reality is not. [38, p. 4]*"

Game Example: SuperBetter

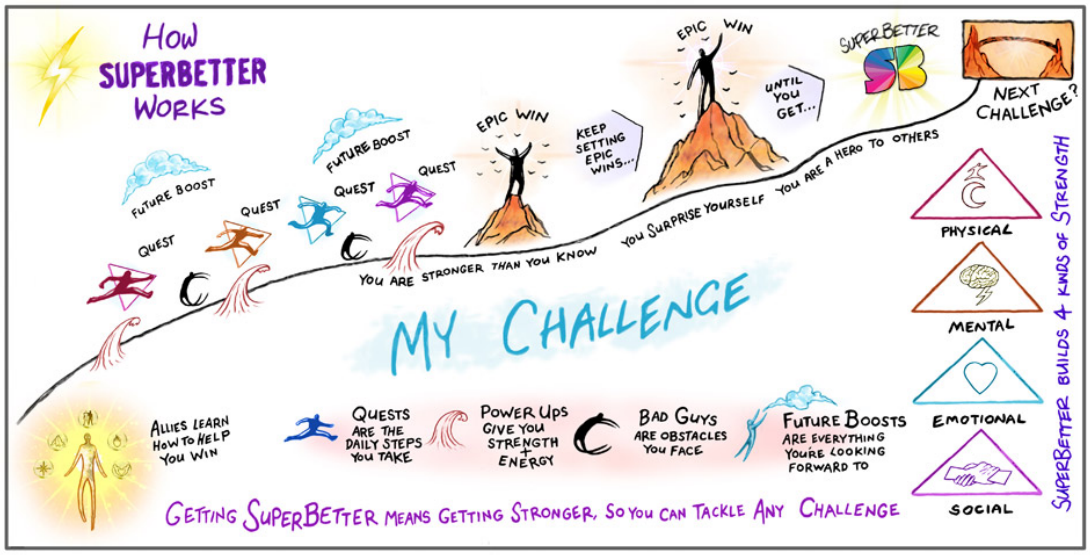

Figure 4.2: SuperBetter is a positive impact game created by Jane McGonigal [39]

> "*SuperBetter helps you achieve your health goals — or recover from an illness or injury — by increasing your personal resilience. Resilience means staying curious, optimistic and motivated even in the face of the toughest challenges. [39]*"

SuperBetter is a game created by Jane McGonigal to help herself to recover from a depression caused by an accident. The idea behind the game is not just to recover but it also tries to make a person more resilient than before an accident, depression or anything else that can make a person weak. The game is divided into the four major areas, physical, mental, emotional and social (see Figure 4.2). To get SuperBetter a person must always work on these four major areas.

It is suggested to play the game with allies to work together on the four areas and to cheer you up. Most of the time quests involve simple daily life tasks like to hug a person or to walk around the corner. All of the game quests and the game itself are based on scientific research.

4.2 Serious Games

> *"Serious games use the artistic medium of games to deliver a message, teach lessons, or provide an experience [40, p. 23]"*

Serious games are games where the main purpose does not lie in entertainment [52, p. 5]. Serious games can be from any part (see Figure 4.3) [52, p. 2] [70, p. 6] [93, p. 12], like the military, government, education, corporate, healthcare, political, religious, art, advertisement, marketing etc. The developer of a serious game normally has a special goal/problem in mind that needs to be addressed. For example, America's Army [81] is a military serious game and it should teach soldiers how battleground strategies work or how to behave after an ABC alert. Serious games can also simulate a person's job in a company where the best player gets a job offer. Or, it can be used to show a person every position in a company. That can help managers to understand what every person works and to get a feeling of the company.

Figure 4.3: Serious Game Relationships [61, p. 12]

The academic problem with serious games is that it cannot be clearly distinguished between other game types. It is a mix of game based learning (GBL), e-learning, classical edutainment games, and entertainment education [37, p. 27] (see Figure 4.4). For example, Microsoft Kinect Dance Central[3] can be seen as an entertainment game. That is what Microsoft probably intended by developing it. It is also an exergame and if it is an exergame, it is also a serious game. Furthermore, it may not only help to have fun and to lose weight or get healthier, it can also teach how to dance. Another example is SimCity (see Figure 4.5). The player learns how economy and industry works; how trading and competition works; or how the transport and garbage collection system works. That means the player learns something by playing the game, if he or she intends it or not.

Another academic problem is the naming itself. The serious game is an oxymoron [20, p. 41]: it sounds impossible that something can be serious and a game at the same time. Some

[3] `http://marketplace.xbox.com/en-US/Product/Dance-Central-3/66acd000-77fe-1000-9115-d802373307d9`

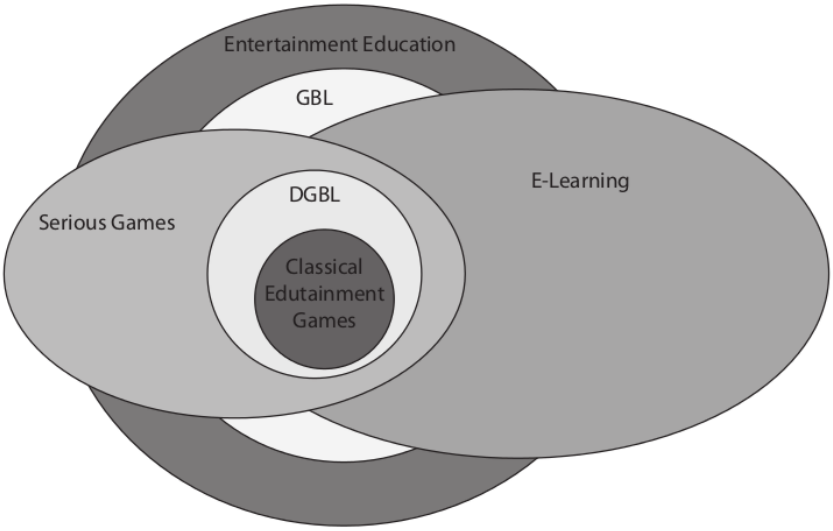

Figure 4.4: Relationships between different educational game types [37, p. 27]

way to walk around this problem is to say serious games unite the seriousness of thought and problems with the experimental and emotional freedom of active play. Even though, serious games have a connection to the "real" world, they are not simulations. A flight simulator itself is not a serious game. But by making a game out of it, that means creating rules and goals, the flight simulator can become a serious game. For example, the player wakes up alone in a flying plane and has to land it. The goal is to land the plane. The importance of the exercise is that, he or she learns how to use all the buttons in a plane, how to communication with the ground control and other important functions. All in all, the main goal is not the entertainment of the player. A serious game acts like a Trojan horse or a Goault (Star Gate) by not recognizing that the player actually learns something while playing.

Games Example: Ludwig

Ludwig is a physics game created for children at the age of eleven and up. The idea behind the game is that children should learn about renewable energy and physics. One major goal for Ovos[4], the creator of Ludwig, was to create a modern 3D game with modern game mechanics. The reasons for that is that many education games are boring and do not reflect the games children play at home. Ludwig tries to have the same quality of a modern game but with a serious background. [48]

The story is about a universe where all common sources are almost gone and the little research robot is sent out to find new sources of energy. On its journey the player must help Ludwig to repair its spaceship which got destroyed during the landing (see Figure 4.6). While

[4] http://www.ovos.at/

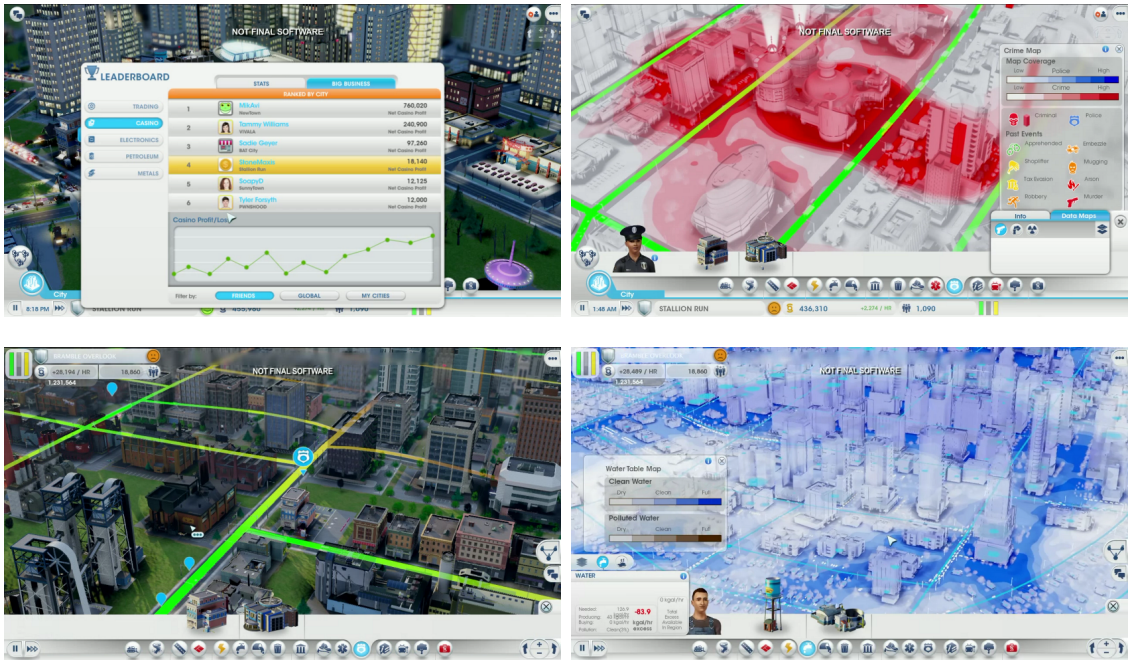

Figure 4.5: SimCity Economy Graph, Crime Layer, Traffic Layer and Water Layer

Figure 4.6: Ludwig is a physics game for children at the age of eleven and up. [48]

finding a solution for Ludwig's problem the player explores many types to harvest energy and to combine physical and chemical elements.

4.3 Art Games

> "*Games are perhaps the only medium which allows us to experience guilt over the actions of fictional characters. [36]*"

Since ancient times, art is being discussed but a clear definition of art could never be made. The same problem counts for video games as art as the following chapter will show. Different perspectives from formal definitions to subjective definitions, given by experts and video game players, will be introduced.

The book "Theories of Art Today" defines items as art "*if and only if (a) it performs a eudaimonistic[sic] function, (b) someone claims art status for it, or for things of the same sort, (c) this claim receives adequate acceptance [7, p. 58].*" Smuts on the other hand formalizes a wider definition of video games as art. He claims that art is defined by "*having a manifest aesthetic, acceptance on institutional grounds, aesthetic evaluation and the role of authors [41].*"

The biggest challenge in defining video games as art lies in the new form of art. By looking at video games with the perspective of an old art form (film, music, painting, writing), video games can clearly be defined as art [92] [36] [32, p. 15]. They use narrative forms like texts for the storyline, as well as sound, images and movements for audio-visual effects [92, p. 162]. All those forms are separately seen as art forms on their own. But in combination, video games are an interactive narrative art form which cannot be accomplished through other art forms. Georgina Goodlander, the organizer of the Art of Video Games exhibition, says "*A video game can't be an artwork, unless somebody is playing it and that everybody has a slightly different experience. [21, min. 0:44ff]*" Seen by this definition, video games are like "The never ending story" or "Groundhog Day". Every time a person plays it, the story is slightly different.

Chris Melissinos, the co-organizer of the Art of Video Games exhibition defines the artwork of a video game in three voices: First, the voice of the author/artist. Every author/artist wants to tell a story. The second voice is the game itself. Every game has a special game mechanic, a special way of interaction with the game world. And finally, the player. The way the player sees and plays the game. The player finishes the game by playing the main quest or many side quests. He or she can be the brutal soldier or the silent soldier. The end of the story can be the same but the way to reach the end is different [36].

The defining process of video games is mainly an academic problem. But why is that even necessary? Jenkins found out: "*At high schools and colleges across the country, students discuss games with the same passions with which earlier generations debated the merits of the New American Cinema of the French New Wave. Media studies programs report that a growing number of their students want to be game designers rather than filmmakers. [34, p. 176]*" Consequently, even if video games are not clearly defined as art, the discussion about video games leads to an inevitable need for definition. Furthermore, video games "can" create emotions in the player like other art forms before. But with the words of Will Wright: "*Games are perhaps the only medium which allows us to experience guilt over the actions of fictional characters. [36]*". One example of this guilt-effect can be experienced by playing the game Shadow of Colossus (see Figure 4.7).

Chris Melissinos describes the experience of playing Shadow of Colossus in the following way: "*My experience with playing Shadow of the Colossus is that the further I got into the game and forwarded the desire of Wander, the protagonist, the worse I felt as a player in doing so. The Colossi that I had to bring down had done nothing to me. They were just living out their existence and it's through this very selfish act that you are forced to bring them down, remove their soul for the protagonist who you are also a ward for. [36]*"

Figure 4.7: Shadow of the Colossus by Team Ico

For this thesis an art game is defined as followed: You play and experience the game, its beauty and the way you and everything moves give you the feeling of happiness or some other not describable feeling. It just fits!

Game Example: Journey

Figure 4.8: The beautiful art game Journey created by thatgamecompany [73]

Journey is the bestseller game in the Playstation store 2012 and won the IGN Game of the Year 2012 award. It is a road game where the player is in a constant mix of walking, flying and magic. The world around the player is simple on one hand but with a lot of details on the other

hand (see Figure 4.8). If anything in the game is important for the player, the player immediately knows where it is and what to do. [73]

But what makes Journey so special compared to other games? The specialty of Journey is that it is a multiplayer game but not a conventional one. On some point in the game, the player meets another person. There is no difference between those two players and every player could walk through the world completely alone. The specialty is that the players can only communicate with a lightning energy ball around the other player that makes a simple sound. When the two players are next to each other and one is pressing the lightning button the energy level of the other player rises. That means the only action a player can do is to signal "Hey, here I am!" and "Hey, here is a little energy for you!". What happens is that the two players try to help each other because they can jump higher and solve the game faster when they stay together. The players never know who the other player is but that is the particularity. The game tells a person it is not important who the other person is, how old, what color, what gender or what language the other person speaks. It does not matter. What matters is to stay together and to help each other. And this is probably the reason why the game is so fascinating.

4.4 Exergames

Exergames are a special type of games where full-body movements or part-body movements are involved (see Figure 4.9). The meaning of exergame is a word combination of the word "exercise" and the word "game" [61, p. 23]. A game like soccer could also be seen as an exergame but in this context, an exergame is always in combination with a computer [61, p. 24]. Embedded in the context of this thesis, exergames are an excellent example of positive impact games whereby the verb play has a direct input/influence on the gamer's fitness level [37, p. 56]. To give a deeper insight into exergames, this section is divided into controller types, goals, target groups, reasons of interests, applications, pro&cons and technical types.

Figure 4.9: Playing an Exergame on a Nintendo Wii Balance Board. [43]

The most striking difference between conventional video games and exergames is the controller. Conventional video games are normally played via keyboard, mouse, joystick or game-

Characteristics	Overall (n=11)	Boys (n=6)	Girls (n=5)
Age (Years)	14.6 (0.5)	14.9 (0.3)	14.3 (0.5)
Body mass (kg)	60.4 (8.8)	65.4 (8.5)	54.4 (4.7)
Size (m)	1.69 (0.1)	1.78 (0.05)	1.59 (0.04)
BMI (kg/m^2)	21.2 (2.5)	20.7 (2.6)	21.7 (2.6)
Energy Consumption at Rest (kJ/kg/min)			
Measured Energy Consumption (kg)	81.3 (17.2)	83.0 (21.5)	79.3 (12.4)
Xbox 360 (kg)	125.5 (13.7)	127.9 (13.2)	122.6 (15.3)
Wii Sports Bowling (kg)	190.6 (22.2)	201.8 (16.3)	177.2 (22.2)
Wii Sports Tennis (kg)	202.5 (31.5)	222.2 (23.4)	178.9 (22.8)
Wii Sports Boxing (kg)	198.1 (33.9)	206.8 (23.8)	187.7 (43.9)

Table 4.1: Energy metabolism of participating test persons on XBox 360 and Wii [61, p. 61]

controller. All of these types stimulate the gamers fine motor skills. Exergames, however, stimulate the gamers gross motor skills. This is managed by "changing" the gamer into the controller. The gamer is not using a joystick to move the avatar in the game. The gamer moves around in reality in order to move the avatar in the game. [61, p. 23]

The most famous consumer exergame controllers on the marked are Microsoft Kinect[5], Nintendo Wii Remote[6], Nintendo Wii Balance Board [43], Sony Playstation Move[7] and Sony Playstation EyeToy[8]. These types can be divided into three technical groups: First, control via motion sensors. Examples are the Nintendo Wii Remote, Wii Balance Board or the motions control unit in every modern smartphone. Second, automated motion detection with cameras and other specialized tracking systems. Examples are the Sony Eye-Toy and Microsoft Kinect. Finally, controllers for a special application like biking or running. On example is the PCGamer-Bike by 3D Innovations[9]. [61, p. 49].

The goals that a developer is pursuing are not always clear while producing an exergame. In some cases, it is the fun factor, in other cases it is the fitness factor or the training factor. However, the main reasons for gamers to play exergames are: to make sport, to burn energy, live healthier and to get better in what he or she is doing, better gesture control and better coordination. Studies have shown (see Figure 4.1) that exergames have a direct positive input on the players fitness level but still have a huge deficit to real traditional games [61, p. 61].

The target groups for exergames are mainly divided into two groups. The first group uses exergames because it is not satisfied with the conventional fine motor skilled human computer interaction controllers. The second group uses exergames because it sees a necessary need in sport activities but gets bored from conventional sport. [61, p. 24]. Nevertheless, gamers mention six types of interests for playing exergames. Those types are the fun-factor, the challenge, the interaction with the surrounding, the simple interaction for all types of person, the challenge

[5] http://www.xbox.com/en-US/kinect
[6] http://www.nintendo.com/wii/what-is-wii
[7] http://us.playstation.com/ps3/playstation-move/
[8] http://us.playstation.com/ps2/accessories/eyetoy-usb-camera-ps2.html
[9] http://www.pcgamerbike.com/

oriented game and the generation of gamers. Generation of gamers means the gamer is interested because he/she is always surrounded by technology and therefore he/she gets interested in technology. [61, p. 54-55]

Applications of exergames can be found in many places. In the school system, exergames create a fun environment to make indoor sport. In fitness centers, exergames are used to create a virtual competition. Projects like Wii at Home [24] are using exergames in rental residences to motivate pensioners for sport activities. Games like PlayMancer [10] are used in rehabilitation to improve motor skills. Furthermore, this thesis project can be seen as an exergame by improving the patient's motor skills [61, p. 76-79].

To conclude, exergames have many positive aspects and impacts on the player, but also negative aspects and impacts. The positive side is, that players are more concentrated on the game not on the sport. Therefore, they do not get bored by doing sports. Furthermore, kids do in general more sport which is important for the current western country fitness level plus they play less conventional video games. Nevertheless, exergames also have negative aspects. First, many games start with a high attraction level caused by a new game challenge or other factors. But they also tend to have a beginning and an ending. That means players play a game only a short period of time until they go back or switch to other media or games. Second, with extensive playing, diseases like Wiiitis [6] or carpal tunnel syndrome will occur by playing Wii Bowling 7h a day. [61, p. 80-81] [61, p. 73]

4.5 Rehabilitation Games

Rehabilitation games, as the name indicates, are games specially developed with a focus on one or more rehabilitation aspects. The following three reasons will give an overview of rehabilitation game benefits. First, the repeating cycle of one special task can be boring and tiring for the patient. A game, in contrast, helps the patient to stay motivated to finish their treatment program [52]. Second, games distract the patient's attention from their pain or disability. Finally, games can give the patient an early feedback what is still possible with a disability. The idea of rehabilitation video games is not a new idea. A widely used game is called RehaCom [25]. The game concept was developed 1986 and the game is more than twenty years of service. The long term use of this game demonstrates the effectiveness of rehabilitation games [52, p. 4]. They have a wide area of applications. It is used in rehabilitation for disabilities following by stroke, traumatic brain injury, chronic pain, motor deficits, coordination deficits and movement patterns [60]. The following section is divided into design principles, input devices, perfect game situation and problems.

To develop reasonable rehabilitation games, special design principles should be included into the design process. By looking at conventional rehabilitation therapy three key concepts, repetition, feedback and motivation, can be seen [60]. Those concepts should also be included in a video game. Especially feedback and motivation can be, in theory, better realized within video games instead of conventional therapy. Schönauer et al. [60] write that the best way for a feedback is an instant feedback. He calls it knowledge of performance. For example, the patient should instantly see whether he or she dropped a ball, instead of only a feedback at the end of the game of how many balls he or she dropped. Nevertheless, the knowledge of results should also

be included. This is especially interesting when the patient wants to see its progress between the last times or to compare with other patients. The second concept is motivation. It is generally harder to implement because it is a subjective concept. Depending on what the patient likes and how skilled he/she is, he/she gets motivated or not. Nevertheless, every game that is motivating includes challenges and meaningful play (see Section [3.5).

Because this thesis is linked with motion/movement rehabilitation, a closer look at input devices is necessary. To monitor the progress of patients, highly accurate devices should be used. The benefits are a simple comparison with the former session and other patients. Furthermore, accurate data is also important for research because the collection of accurate data increases the efficiency of the application by integrating this knowledge in the next update [60]. Schönauer et al. [60] describe four requirement input devices for movement rehabilitation. First, the tracking of movements must be stable and reliable. Second, at least six degrees of freedom (DOF) should be used. Third, the device should return feedback in real-time. Finally, recorded data should be comparable between patients and therapy sessions. To add a "even" higher level of accuracy, biofeedback devices for vital information can be implemented. Those devices are used to measure heart frequency, blood pressure, breathing, temperature and other vital information. Technically, rehabilitation games are overlapping with exergames. Common tracking devices can be seen in section 4.4.

By implementing a rehabilitation game, a perfect situation could look like the following: Every game parameter plus player parameter can be calibrated before or during the playing. This is important because only well calibrated devices return accurate and more importantly comparable data. A game should be configurable by the therapist. This is important because every patient is different. Furthermore, the gameplay should also

Even though, rehabilitation games bring an interesting view into rehabilitation, most of them share some common problems. First, they are all in prototype stadium, which means a game is created in a university and is used for research. Second, the game is tested with only a few patients [60]. Those two problems make it hard to create a comparison between different games and approaches.

Game Example: Playmancer

> "*The majority of participants (90%) would recommend this "serious gaming modality" to be added to their current rehabilitation treatment. [60]"*

Playmancer (see Figure 4.10) is a rehabilitation framework that can be combined with different technologies. Depending on the patients need, technologies like motion detection or a treadmill are connected with the framework. The benefits of using a computer game in combination with special technologies are that the patient has fun while playing the game and that the therapy progress can be measured very accurately. [60] [10]

The game itself is divided into three mini games. First, the Temple of Magupta. The player needs to run on a treadmill through an ancient temple to collect artifacts and avoid obstacles. The aim of this exercise is physical reconditioning which should increase the walking speed. Second, Face of Chronos. The player needs to climb up a mountain and collect artifacts. To climb up the patient needs to extend his or her arms upwards to find a holder in the mountain.

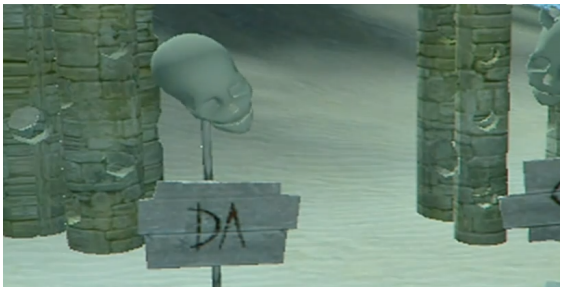

Figure 4.10: A rehabilitation minigame in Playmance against neck problems. [23]

This exercise increases the reaching ability, relaxation of the muscles and the smoothness of the motion. The last game is called Three Wind Gods. The player must imitate a variety of head movements. The sense behind this exercise is to enhance the smoothness and velocity of the cervical motion (neck motion).

4.6 Conclusion

To create a rehabilitation game that has a positive impact on the patient several game types need to be included. Because of the special situation of the patient a game should be flexible and motivating. Every rehabilitation game is in some kind a serious game. The idea is to create a serious impact on the patient's health. In many cases rehabilitation games also include physical movements which makes them into exergames. By adding parts of art games, the game becomes more beautiful and interesting to play. The player gets a feeling that their actions in the game matter. Furthermore, art games can help to work on the psychological rehabilitation. It can show different ways in which a situation can be handled. At the end, a rehabilitation game should be a positive impact game. The patient should learn something for his or her life to handle special situations.

CHAPTER 5

The Game development process

Due to the special situation in which the patient is located in, it was important from the first day of conception that the game should reflect the current situation of the patient. After a traumatic loss, the need to work on the patient's life balance is as important as to work on the patient's physical rehabilitation. While playing the game the patient should not only learn how to handle a myoelectric interface (see Section 2.1) and later a prosthesis, the patient should also be able work on his or her psychological situation. The optimal outcome is a patient who feels stronger and more resilient than before the accident/loss of the limb. In other words, he or she should be SuperBetter (see Section 4.1).

To understand the patient's needs and to create a working proof of concept, a research investigation was needed in the field of game design, rehabilitation, psychology and physiology. A special mix out of explorative design methods, interviews and paper research was used to understand the needs of a patient. Unfortunately, a user centered design process was not possible because of the project time and the ethnic prerequisites. To be allowed to work with humans with disabilities, the ethnic commission must proof the project and that would overstretch the scope of a diploma thesis.

Based on the virtual reality rehabilitation project (see Figure 5.1) created at the Interactive Media System institute at the Vienna University of Technology and in combination with Otto-Bock, the first design session was held on the 4 October 2012 (see Section 5.6). The design session started with a discussion about the pros and cons of HMD, augmented reality and virtual reality. The following discussion was based on the question if the game should reflect a real life environment like a kitchen and a house or rather a futuristic environment like a dream world or a fairy tale. Since the myosensor (see Section 2.1) used in the project is not able to produce a haptic feedback, different types of audio-visual feedback were discussed. The last topic was about the prosthesis itself. What is possible with the prosthesis and what type of virtual hand should be used? Similar to the question about a real or futuristic environment, different types of hands were discussed as well (see Section 5.2).

At the end of the session, a clear game idea was born plus one new fundamental question. The game idea was a mashup of Hulk and Katamari (see Figure 5.2) but in the opposite way. It

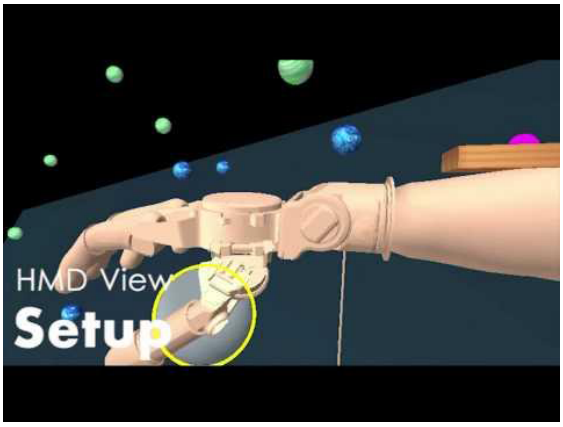

Figure 5.1: The Otto-Bock virtual reality showcase

can be called a De/Anti-Hulk game. The game principle was based on the idea that the patient is very angry at the beginning. The Hulk should reflect the person's anger. While playing the game the patient learns how to handle his or her anger and gets smaller and smaller. Katamari on the other hand, is part of the concept because the Katamari can get as big as a planet and the concept created by Otto-Bock has similarities with a giant that is bigger than a planet (see Figure 5.1). With the idea of a deformable player (De-Hulk), the need for a deformable hand was born. The first idea of this deformable hand was a wooden stick that falls apart while playing and gets the form of a real hand at the end of the game. The one fundamental question which was born during the session was: is an HMD or a normal screen the best way for playing this type of game. The concerns were based on the fact that HMDs are not immersive enough to create a real virtual reality feeling but on the other hand a normal screen is able to create a good enough 3D world to interact accurately with objects on a different depth level.

Figure 5.2: Katamaria [72] and Hulk [27]

5.1 The Road Movie/Rails Game

As already mentioned in section 5, the game should reflect the current situation of the patient. One expression to reflect the patient's situation is the road movie/story. Road movies/stories are frequently used in narratives, movies, songs and games. The idea is that the main character learns something for his or her life or changes his or her characteristics while he or she walks through the adventure. One famous example is Lord of the Rings. Frodo, for example, is a happy young innocent hobbit at the beginning of the story. He did never see anything bad in his life and everything was perfect. While he is walking through middle earth, he sees more and more blood and is confronted with his and the worlds evil side. Frodo changes from a nice hobbit to a heavily loaded man who can hardly handle the burden of being the only hope for a free world.

The second characteristic that many road movies/stories have in common is that the surrounding reflects the situation of the player. By using the example of Frodo and Lord of the Rings (see Figure 5.3) a second time, it can be recognized that the inner harm Frodo feels is reflected by the nature which gets darker and less lifelike over time. At the beginning, when he is happy the nature is green and everywhere are flowers. At the end of the story, Frodo is in the middle of a dead place where no flower can grow and all he sees is fire, lava and death.

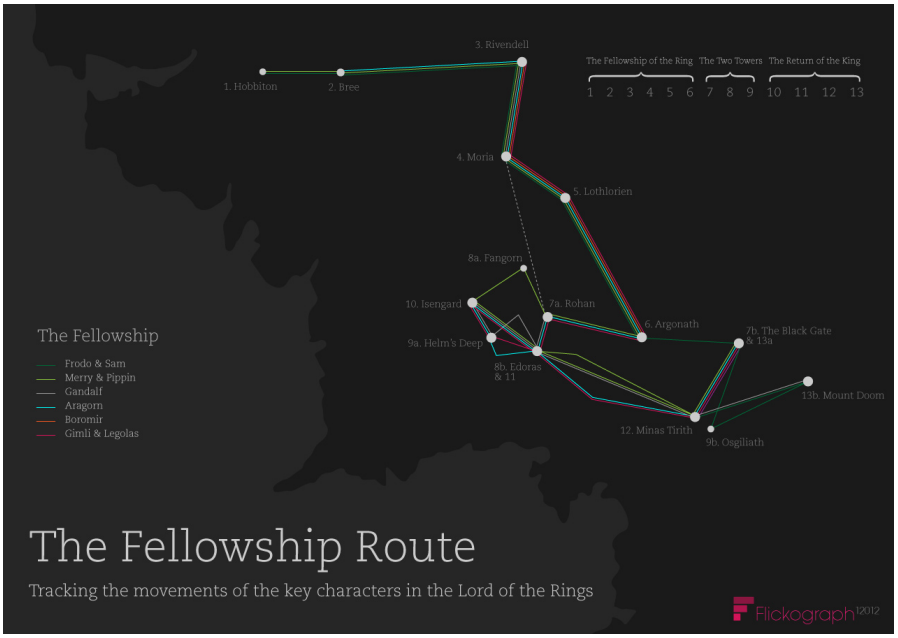

Figure 5.3: The Fellowship path through middle earth. The dark green path is Frodo's & Sam's. [17]

A patient who just lost its arm is in the opposite situation of the one that Frodo was in at the beginning of his journey. The patient is angry, sad and in a very difficult situation at the beginning of his or her journey. By reflecting his or her situation, the game starts in a dark and sad place. The patient should be allowed to get rid of his or her anger by destroying things.

While playing the game, the patient gets calmer and he or she can "differ" between good and evil. His or her "new" situation is than reflected in a nice and more loving nature. At the end of the game, the patient should be able to handle his or her prosthesis plus he or she should have learned something for his or her life to handle the loss of an arm. A first draft can be seen in figure 5.4.

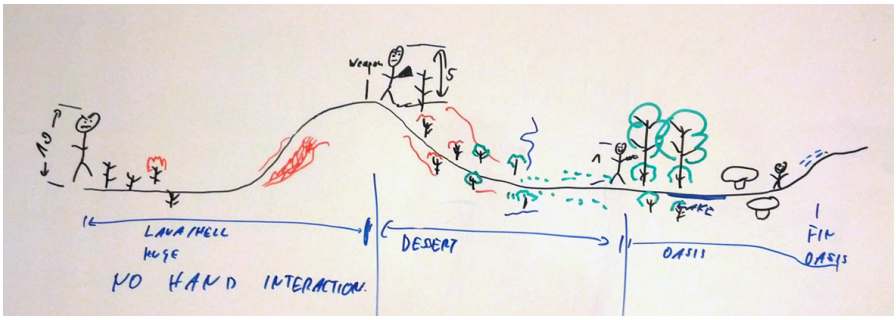

Figure 5.4: First road map draft. The patient is angry at the beginning and gets happier towards the end.

5.2 Magic Hands and Interactions

To create a fun and exploring game experience, a special focus must be taken on the interaction between the player and the game world. In this particular case, an even deeper focus must be taken on the interaction with the virtual hand. During an interview with Andrei Ninu, an Otto-Bock employee (see Section 5.6), the main functions of the prosthesis were separated into the three activities: opening, closing and neutral (see Figure 5.5). Every action can be executed with and without the thumb. The prosthesis makes it possible for the patient to hold an object in his or her half closed hand or grasp something like a glass of water.

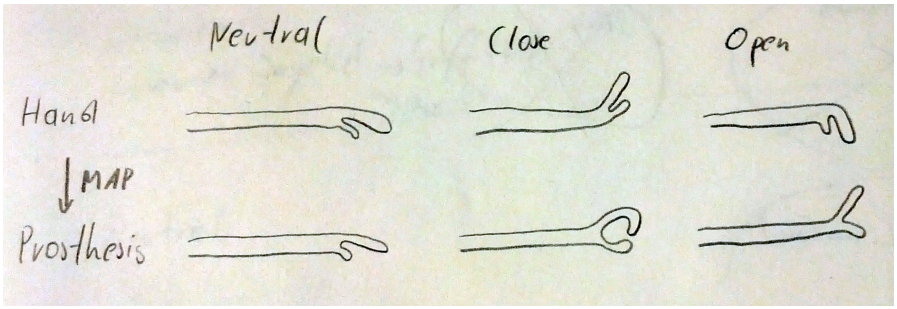

Figure 5.5: The three prosthesis stages neutral, closed, open

By setting the possibilities of the virtual hand in the middle of the interaction, a special type of hand that can change its shape, from now on called magic hand, was created. The idea behind the magic hand has many similarities between Super Mario and the Super Mario mushrooms.

Many Super Mario maps are divided into mini games. In this case, Mario can eat a mushroom and transform into a special type of Mario. Only with his new ability, he can solve problems. The interesting characteristic about this game concept is that Mario does not get stronger and will have this ability throughout the whole game; he has it just in one level or for one mini game. It gives the game creator the possibility to create completely new challenges and different interactions over time. This concept is perfect to extent a game over time, which can be seen in over twenty Super Mario [42] games and more than hundred titles [77] featuring Mario. Figure 5.6 shows Mario as Bee-Mario and as Spring-Mario. As Bee-Mario he can fly and climb on honeycombs and as Spring-Mario, he can jump higher.

Figure 5.6: Bee-Mario [91] and Spring-Mario [90]

To create different challenges in the game, many drafts of magic hands were created. With every magic hand the player can solve another problem in the game. In the following part of this section, different drafts of possible magic hands are discussed.

The Light Hand

The light hand (see Figure 5.7) is normally just a flashlight. The player can use it to navigate through a darkness. But it can also be used to shine at plants like flowers and to let them grow by using photosynthesis. If the light is a fire it could be used to defrost some areas or plants.

The Destroy Hand

The destroy hand (see Figure 5.8) is simply created to destroy things. The idea behind it is to get rid of inner aggression by destroying virtual objects. It is also a tutorial hand that gives the patient the possibility to learn about force and speed in the game.

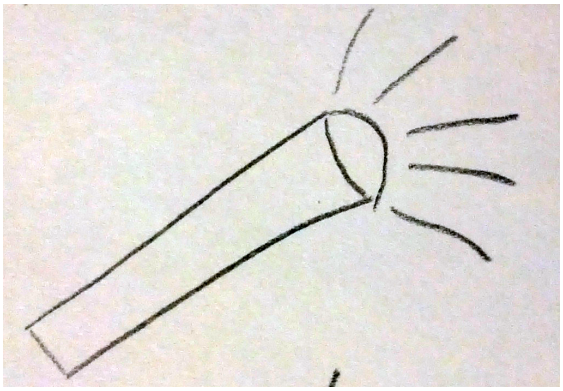

Figure 5.7: Light Hand: A magic hand that can glow.

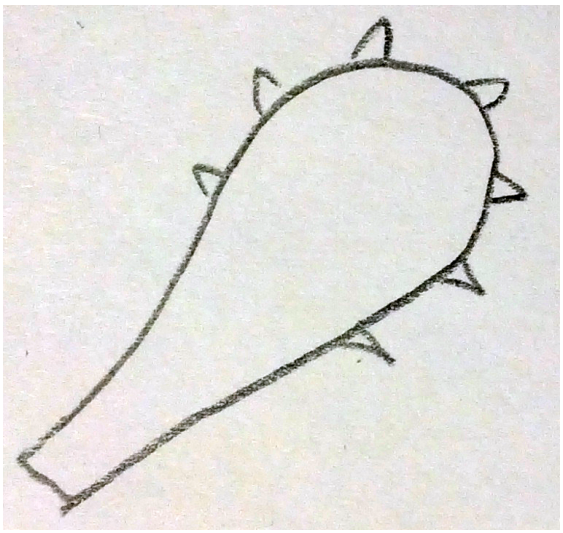

Figure 5.8: Destroy Hand: A magic hand to destroy objects.

The Spoon Hand

With the spoon hand (see Figure 5.9) the player can hold a variety of elements in its hand. This type of hand can be used to learn how to balance by adding a ball into the spoon hand. It can also simply be used to play simple physic games with liquid which must be moved from one bottle to another. The patient can learn to get better fine motor skills.

The Fountain Hand

The fountain hand (see Figure 5.10) spills water. A simple use is to spill on dead plants which start to grow. In this way, the patient can "create" new life and gets a better feeling how it is if someone needs help. This is especially interesting because it is fairly hard for many people

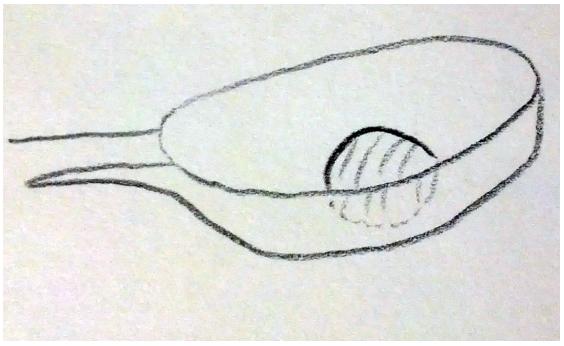

Figure 5.9: Spoon Hand: A magic hand to transport fluid.

to handle help from outside. Most people were used to manage everything on their own before they lost their arm.

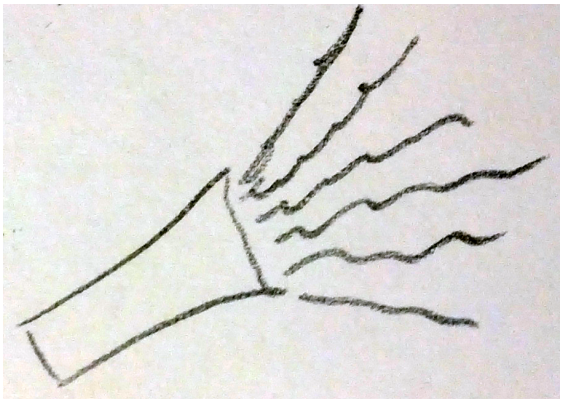

Figure 5.10: Fountain Hand: A magic hand that spills water.

The Grasp Hand

The grasp hand (see Figure 5.11) is the most advanced and most similar hand to a real prosthesis. It can simply be used to drag nearly every type of object. With this hand it is possible to turn objects around, to solve a puzzle or other problems. Furthermore, the patient can learn how much he or she is allowed to squeeze an apple or a banana until it is damaged. A visual feedback is very important in order to learn how to handle different forces on different objects.

With the help of the magic hand drafts given above, many more new magic hand and game challenges can be created. The benefit of this concept is to adjust and recreate new challenges over time. In this way, the research results can easily be integrated during a new design/feedback loop.

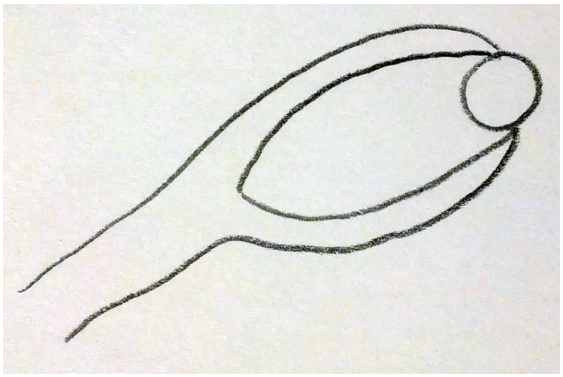

Figure 5.11: Grasp Hand: A magic hand to grasp objects.

5.3 Final Game/Showcase

To combine all the information collected during the research process for this thesis, one mini game was created. The outcome of this mini game is a showcase which gives a direction for future work. In the following section, the most important design decisions are described.

General Game Idea

The general game idea was to create a game where the patient can work on its physical level and on its psychological level. As discussed in section 5.1, the psychological level should be reflected by the game world. At the beginning, an open world should be created. The player could run around everywhere in the world. Unfortunately, this concept brings some major issues for a one person development. First, an open world is too big to create in a reasonable time and second, the player should be more concentrated on the challenges as on the game world. To bypass this problem, a rails game was set into the open world. With this concept the player has the feeling of being in an open world by not leaving the path the game designer created. It was possible with the benefits of a rails game that the player never misses any important object in the game. In this case, it was clear that the player is going to try every challenge before he or she gets to the next step. A detailed description of all principles and decision are listed in the following section.

The Giant

To make sure the patient never gets the feeling of being in danger, he or she starts the game as a giant. Or better a giant tree. Since the game is played through a first person perspective, the player cannot see itself and it is hard to understand that the player is a giant. To solve this problem, audio and visual effects are used to give the player the feeling of being a giant.

Every time the giant makes a step the world starts to rumble and a loud thunder can be heard. Furthermore, a special visual effect called "Tilt Shift" is used to create a miniature faking. With

the miniature faking all objects in the game look smaller than they are. An example can be seen by comparing the two pictures in figure 5.12.

Figure 5.12: The tilt shift effect creates the illusion that objects appear smaller than they are. [15]

While playing the game, the player gets smaller and smaller. Currently the character can have three sizes. First, the giant, second, a size between the giant and a normal person and third, the size of a person. By doing so, the game world itself becomes more lifelike over time/distance. This is important because of the "safe zone" the patient should always be located in. A closer focus on the transforming game world will be taken at next section.

The Magic Hands

To learn how to navigate and look around in the game, the player does not have a magic hand at the beginning of the game. By walking over a "Destroy Hand" lying on the ground, the player gets/grows its first magic hand which can be seen in figure 5.13. The first challenge is to destroy all dead trees by hitting them at least three times on the way to the top of the mountain. The learning effect is to get a feeling for the virtual space and how to move the hand in a virtual space.

Arriving at the top of the mountain, the second magic hand - "Fountain Hand" with a bottle of water - is lying on the ground. The player collects the bottle with the "Fountain Hand" by walking over it. By holding the "Fountain Hand" into the bottle and tightening the muscle spec-

Figure 5.13: The Destroy Hand lying on the ground and the view after the collection.

ified for closing the prosthesis, the "Fountain Hand" starts to absorb water inside. By tightening the muscle specified for opening the prosthesis, the "Fountain Hand" spills water like a fountain until the hand is empty. The second challenge is to wipe out all burning trees on the way down to the valley. The learning effect is to find out how to work with the myosensor (see Section 2.1) and how the sensor reacts in combination with the virtual hand. The implemented "Fountain Hand" and the burning trees can be seen in figure 5.14.

Arriving at the valley, new dead trees can be found. This time the player will not get a new magic hand. The situation with the "Fountain Hand" stays the same but instead of wiping out

Figure 5.14: The Fountain Hand lying on the ground and the interaction of wiping out a fire.

burning trees or destroying dead trees the player must water the trees until they start to bloom and turning into a nice green tree. The learning effect stays the same as in the previous challenge and only the challenge changes. The interaction of watering and growing trees can be seen in figure 5.15.

At the end of challenge three, the player find a "Grasp Hand" with a basket. The player has now the size of a normal person and the game world is full of small plants like mushrooms and flowers. The challenge is to collect the mushrooms and flowers and put them into the basket. The learning effect is to handle the force of the grasping hand precisely. If the player uses too

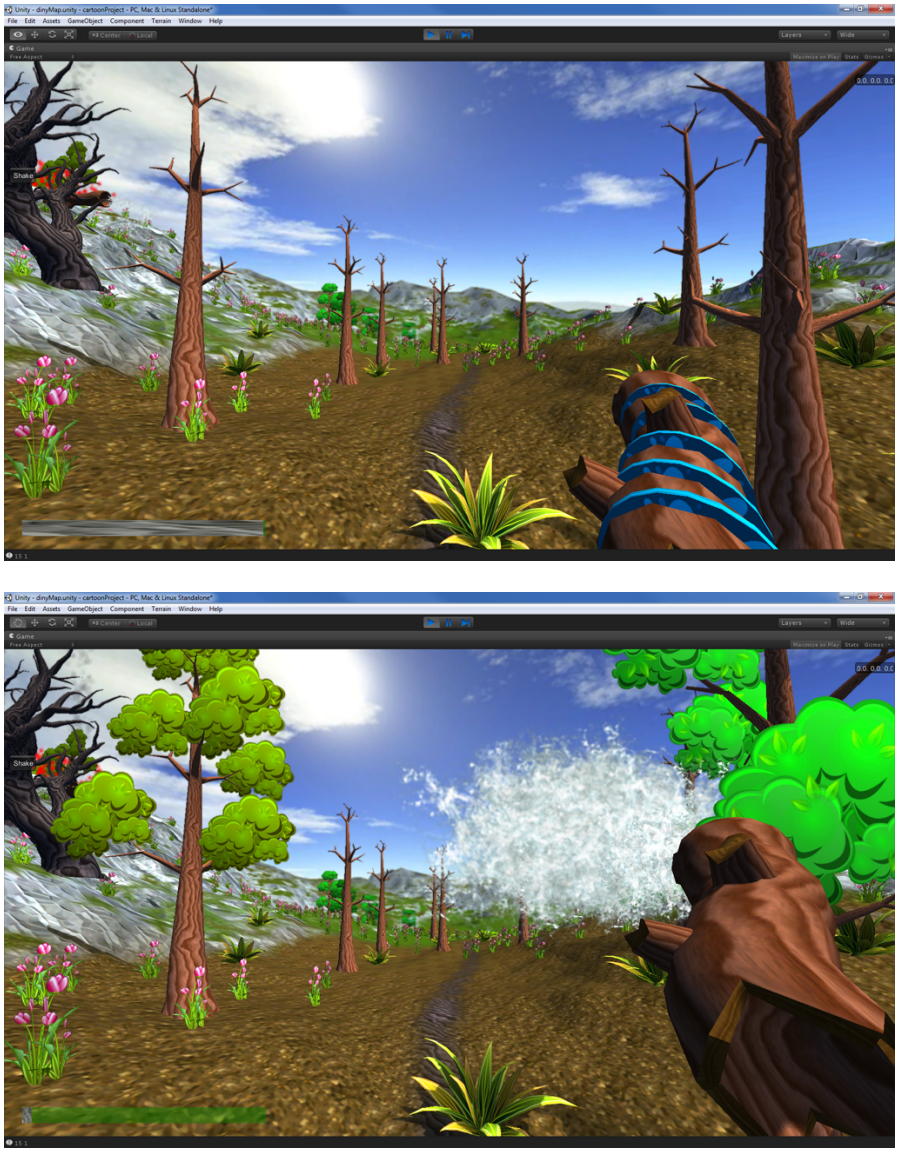

Figure 5.15: The full loaded Fountain Hand and the interaction of watering a tree.

much force on the mushroom he or she will destroy it and if the player uses not enough force he or she will lose the mushroom before it can be put into the basket. (This part of the game was not implemented at the moment of writing.)

The Game World

In addition to a giant as a character, the game world reflects the psychological situation of the patient and changes with the patient's situation. To decide in what design direction the game

world is allowed to go the display systems HMD/screen and the concept of presence (see Section 2.4) need to be included into the decision. To create a situation sensitive game world, the four major level parts: death, help, create and enjoy were created. In addition to the different level parts, a decision between a photo realistic and a cartoon world was taken.

The decision to create a photo realistic or cartoon world was influenced by two factors. First, the question if it is a good idea that the patient finds him- or herself in a real world. By looking at section 2.4, the wrong impulse can create a new anxiety. To limit this risk, a cartoon world was chosen. Second, the factor resources. While game studios have designers, game developers, researcher, money and time, the resources for a master thesis are limited. To create and develop a virtual world as quickly as possible the Cartoon Nature Pack created by On-Q Creations [45] was used. Some impressions between the cartoon world package and a realistic package can be found in figure 5.16. With those two decisions, a positive and consistent game world could be created.

Figure 5.16: The cartoon versus real world Unity3D game pack from On-Q Creations

The world map is a many miles large map which contains a desert, a lake, mountains, a vegetated area and a desiccated landscape. The map is shown in figure 5.17 and 5.18. With this natural environment, different scenarios for various challenges in the showcase were made. Furthermore, it gives the potential for future challenges.

To reflect the patients psychological situation, the four distinguished situations death, help, create life and enjoy are implemented. The final situations are visualized in figure 5.18 and will be discussed as follows.

Death At the beginning of the game the world is dark and the nature is burned and dead. It reflects a world that is not very lifelike. A world that is filled with anger and hate. The idea is to reflect the patient's inner rage on its recent loss. To give the patient the potential to work on his or her anxiety and hate, he or she can destroy everything in the world. This mechanism should help to calm down and work on the frustration. Figure 5.19 gives an impression of this part of the world.

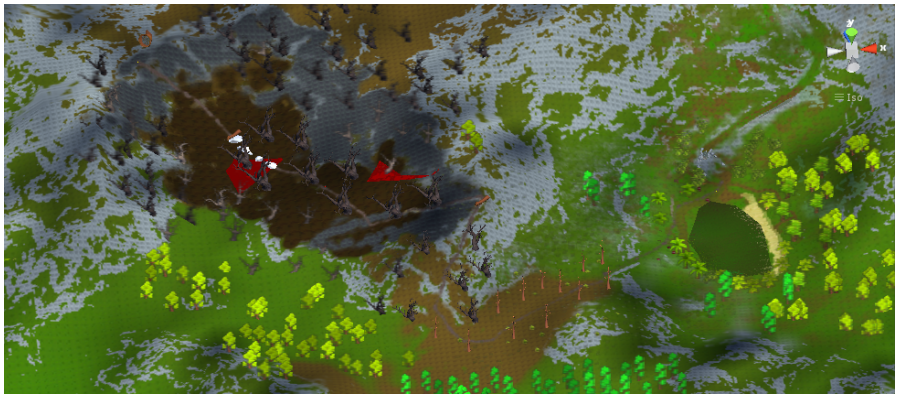

Figure 5.17: The final 3D Map

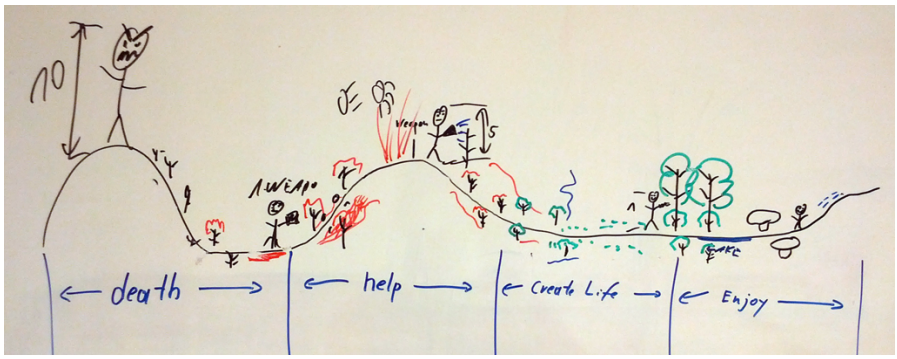

Figure 5.18: The final map situation

Help After the patient has learned how to handle the frustration, the world changes into a nicer place. The sky changes from dark to blue and a beautiful area can be seen in the distance. The patient should get a feeling of a happy future but on the way to this future he or she must take some more challenges. From now on the player is able to splash with water. In this part of the game the player must wipe out burning trees. This mechanism should help to understand the feeling of getting help and to learn how to help. Figure 5.20 displays the view the player has when he or she reaches the top of the mountain and visualizes the wiping out of the burning trees.

Create Life In the next area when all fires are wiped out, the player must water trees and plants to grow. By splashing water at trees they are turning from being withered into beautiful living green trees. This mechanism should give the patient back the potential to believe in him- or herself to create new life and a new wonderful future. Figure 5.21 visualizes the growing and the withered trees.

Figure 5.19: View of the death nature.

Enjoy The last part of the game is not filled with an interaction so far. It contains only an oasis with a natural soundscape where the player can just stay and enjoy the wonderful world. A potential future challenge can be that the player collects nice looking mushrooms. A description of this idea can be found in section 5.3. In figure 5.22 some impressions of the oasis and the nature are given.

5.4 Game Environment Setup

The following section describes how to set up the environment with Unity3D and gives a short overview aver all scripts created for the game.

How to control the character

Two ways are implemented to control the character: First, with keyboard and mouse and second, with Wii-Remote and mouse. To combine the game with the implementation by Otto-Bock, the hand tracking must be mapped on mouse pointer and the myosensor (see Section 2.1) must be mapped on the splash water and absorb water keys.

Keyboard and Mouse The keyboard and mouse keys are all digital keys. This makes it impossible to turn the character to a specific position. By pressing the turn left or turn right key the character turns around until it stops on its own.

W-Key Walk forward

A-Key Turn left

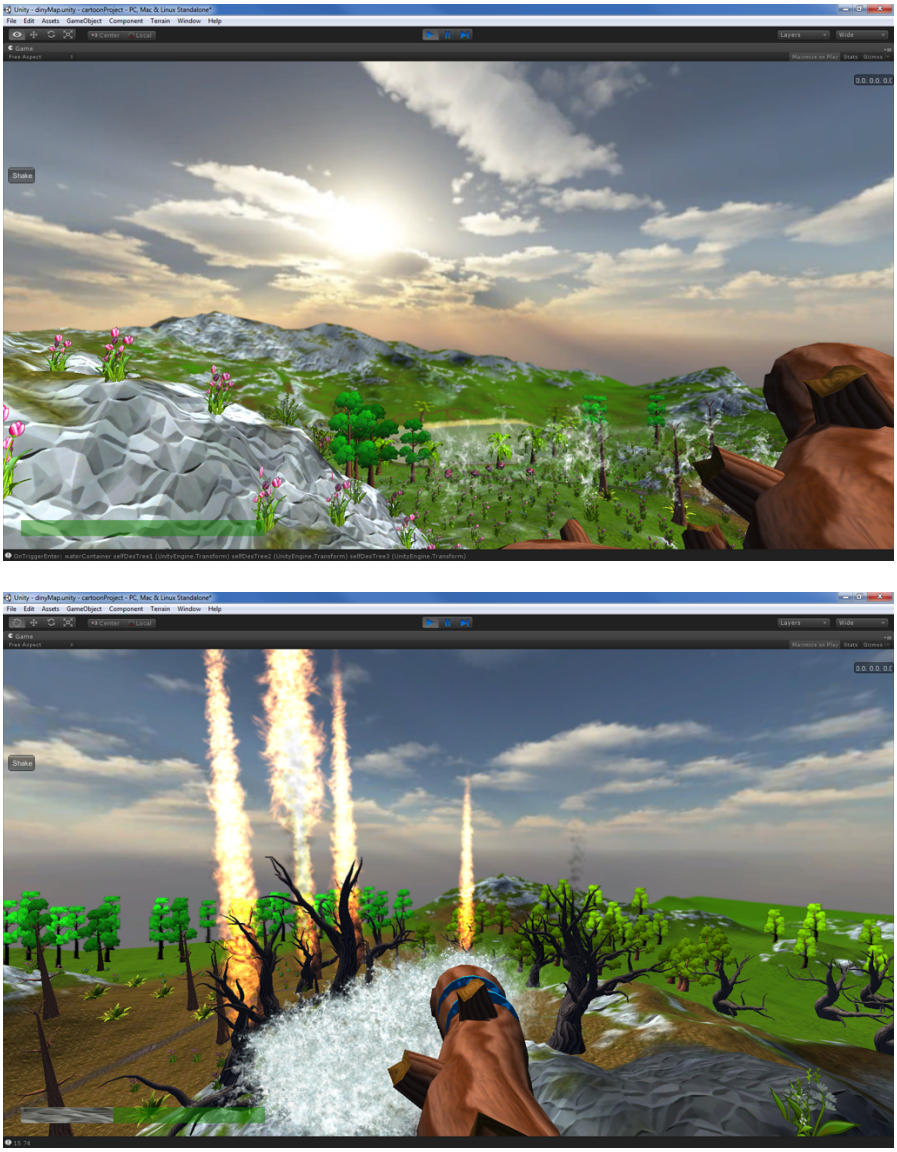

Figure 5.20: View of a beautiful future and the interaction of helping the trees to stop burning.

D-Key Turn right

Mouse-Pointer Moves the magic hand

Mouse-Left-Key Splash water

Mouse-Right-Key Absorb water

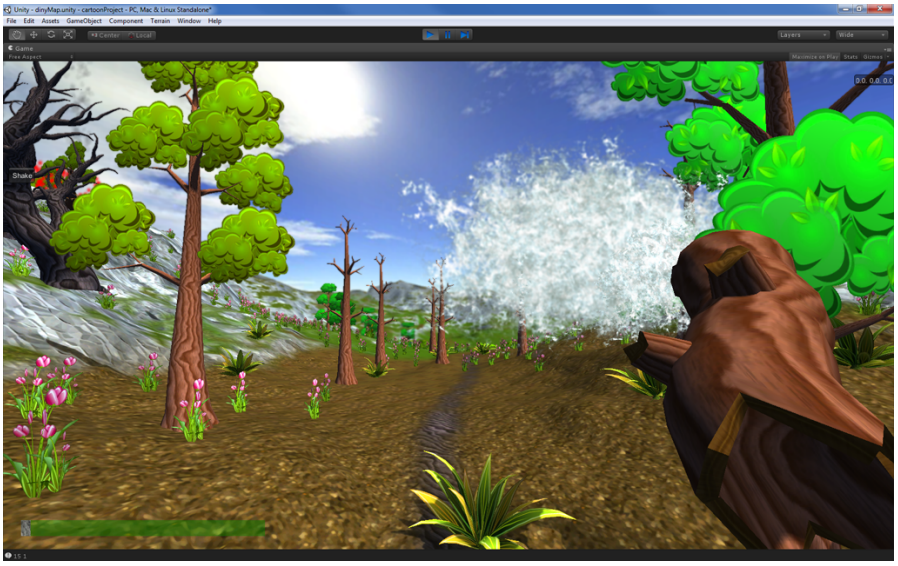

Figure 5.21: The watering of dead trees to create new life.

Wii-Remote and Mouse In comparison to the keyboard, it uses the Wii-Remote as an analog stick. This makes it possible to turn the character to a specific position.

Analog-Key Forward Walk forward

Analog-Key Left Look left

Analog-Key Right Look right

Mouse-Pointer Moves the magic hand

C-Wii-Key Splash water

Z-Wii-Key Absorb water

Short Script Description

Unity3D is a script based game engine. That means, the game developer can add a script to every game object[1] which can than dynamically change the game objects properties. The following section gives a short introduction to the most important scripts written during the implementation of the game.

GameOptionsScript The GameOptionsScript is the central options script. All global environment properties can be set and are visualized in this script. Every script that changes on a global scale links to this script. The following list gives a short overview about its properties.

[1] A game object is every object that is part of the scene.

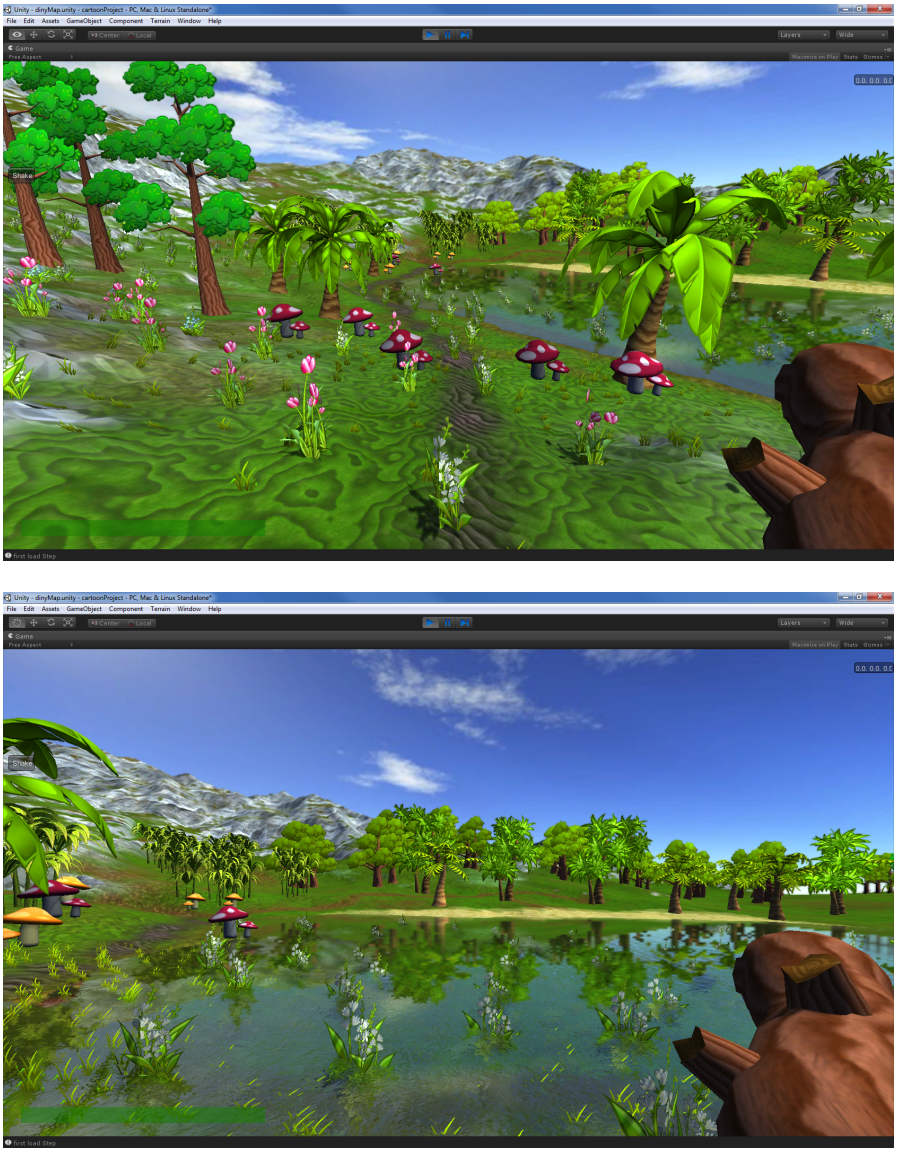

Figure 5.22: The way to the beautiful oasis what ends in a place of peace and joy.

playerRunSpeed Set the maximal speed the player can run.

playerStepMult The factor between the highest and lowest point of the character while making one step.

playerStepLenght The length of one step.

playerRotMax Maximal rotation in degrees to the left and right.

cameraShakeIntensity Shake intensity after one step. This value must be adjusted for different screen sizes. According to the Pythagorean Theorem leg a and b become smaller/bigger if alpha stays the same and the hypotenuse (c) changes.

cameraShakeDecay Defines how long one shake duration lasts.

cameraIsShaking Debug value to visualize if the shake script is running or not.

giantHeight The maximum giant height.

giantXRotation The rotation of the horizontal view.

handDistance The body to hand distance.

handScale The hand size

handWaterSec How many seconds can the water splash

handWatering Debug value that indicates if the water splashes

tempCreateHand By setting this value during playing the character grows the magic hand before it walk over one

wiiC Indicates if C-Wii-Key is pressed

wiiZ Indicates if Z-Wii-Key is pressed

wii Indicates how many Wii-remotes are connected

wiiAlpha Indicates the alpha value of the Wii-Stick

wiiX Indicates if X-Wii-Key is pressed

wiiY Indicates if Y-Wii-Key is pressed

walkDist The absolute euclidean distance the player walked

percentWalked Percentage of the distance the player walked so far

maxGiantHeight Indicates the giants height at every point in the game

middleSky Sets the sky map when the player is in the middle of the game

lightSky Sets the sky map when the player is at the end of the game

CameraShake Shakes the Gameobject when running its public DoShake() method. The intensity and duration can be set via GameOptionsScript.

destHitTree Is member of the Destroy-Hit-Tree prefab and gets triggered when colliding with the magic hand. It replaces its parent tree with a less complex tree to simulate a destruction of the tree. The maximum hit count is three.

growHitTree Is member of the Grow-Hit-Tree prefab and gets triggered when colliding with the magic hands water particles. It replaces its parent tree with a more complex tree to simulate a growing of the tree. The growing is divided into five steps.

unfireHitTree Is member of the Unfire-Hit-Tree prefab and gets triggered when colliding with the magic hands water particles. It stops the flame after hundred particle collisions.

finderTipTreeForward Simply forwards the OnTriggerStay event to its parent script.

fingerTipScript Manages the magic hand function as splashing and absorbing water plus the mapping mouse to magic hand.

followColl Is member of the "follow" gameobject that moves along the character path and gets triggered when colliding with a magic hand lying on the ground.

followFollow Contains all methods to move and rotate the character on the path. All its properties can be set with the GameOptionsScript.

rotateScript Simply rotates its parent.

List of used plugins and other game packages

UniWii UniWii is a open source plugin which is free for non-commercial use to manage all Wii remote functions. This plugin is used in the game for walking, splashing, absorbing and looking. Copyright 2009 ByDesign Games SARL

Spline Controller Spline Controller is a free open source plugin licensed under the LGPL [18] to create a path for game objects. The plugin is used in the game to control the characters walking path.

Cartoon Nature Pack v2 The Cartoon Nature Pack v2 [45] is a full asset package with trees, flowers, terrain and sky. The package is created by On-Q Creation and can be bought in the Unity3d asset story. It is used for the complete game world and for the character. The benefits were that the game world's looks and feeling are consistent and no effort had to be taken in 3D modeling .

5.5 The Plot

After thousands of years, a land ruled by an evil wizard, the Tree of Life came back to show the land the beauty of life. But unlike normal trees, the Tree of Life reincarnates as a giant tree. As it came back, it realized the devastation the evil wizard has imposed on the land. As it got really angry, it seemed that the madness and evil of the country slowly overtook the Tree. It started to lose its beautiful leafs and its power to create life. It was slowly turned over into a tool in favor

of the evil wizard. The tree started to destroy its surrounding and every step it took created a quake.

The Tree of Life with all its wisdom and knowledge of previous lives knew that the evil wizard will most likely overtake the whole country. The Tree itself though is the essential opposing balance to the evil wizard. With that, the Tree of Life prepared itself for a reincarnation. It hid its skills all over the country, so it could get it back when the time has come. Now, it is your turn to find these skills and help the Tree of Life to gather its strength and help the country to become a better place again.

5.6 Meetings and Interviews

Interview with Andrei Ninu, 2012 Sept. 17th

First, we discussed about the probability for an accident which creates such a major damage that a person loses its arm. He told me that according to his experience and knowledge, the major group are young workers. Most likely man. Furthermore, he said that the insurance company must find a good reason to buy the patient an advanced prosthesis from Otto-Bock. If the person who needs the prosthesis is an old man and he was not employed anymore, the insurance company will not pay for the prosthesis.

In the second part of the interview Andrei told me that Otto-Bock can in theory assemble a prosthesis overnight. The problem for a patient to use a prosthesis does not lie in the prosthesis itself but in the healing process for the stump and to create a perfect shaped socket for the stump. To create a perfect socket, the patient needs to work with his or her therapist for months. After that, the prosthesis can be used. The time between the amputation and the fully working socket is where Andrei's virtual reality framework takes places. This is the time when the patient can start with the rehabilitation and the training with the prosthesis without wearing a working one.

In the third part of the interview, he showed me the prosthesis and what they are able to do and what the patient needs to learn. He said, in general the prosthesis has three functions: opening, closing the hand and to stay neutral. Each of these functions can be combined with the thumb at the top or at the side. In this case, the prosthesis can be used to grasp an object or to hold something in the prosthesis. A draft of the three functions can be seen in figure 5.5.

Game sessions in the institute, 2012 Oct. 4th

I started in the morning to tell the group, consisting of Peter Purgathofer, Fares Kayali, Josef Ortner, Lev Ledit and Peter Vorlaufer about the problem/idea and we watched three videos. Video 1 [2], Video 2[3], Video 3[4].

First we had a discussion about HMD systems and Augmented Reality. Some people thought it would be a better idea to use the real environment, like a kitchen but with virtual glasses. In that case, the patient can train how to use the prosthesis in real life but without destroying real

[2] http://www.youtube.com/watch?v=vega9xQj4Hk
[3] http://www.youtube.com/watch?v=pOgfuDrtZyc
[4] http://www.youtube.com/watch?v=3zSgjhZ-cIc

glasses if he or she is not managing it in the first place. This thought came from the assumption, if a person uses the real prosthesis the first time, he or she will for sure destroy something and at some point he or she will be afraid of re-trying the task and might fall in an small aggression or depression. According to the group experience in virtual reality, we all agreed that HMDs are not good enough. The question was, should we really use HMD or is a big screen enough. We never came to a final answer, but the game should/could work without HMD, depending on the story.

Later on, we thought about the feedback from the prosthesis to the body. As haptic feedback is broken, we thought about other feedback types, like sound and visual effects. The visual feedback could be managed with a squeeze able gummy glove/surface. In that case, the patient sees how much pressure he or she is using. With games similar to food ninja, the patient can learn how much force he or she needs to use. (gasp the object but do not destroy it). The same idea can be used with audio feedback but this time, the patient tries to find two similar waves.

One problem we always had was the discrepancy between a real world simulation like tennis, hammer, painting, or abstract things like weird weapons. We came to the result, the patients should learn themselves how to solve the problems we create, and it is not important if the objects are "real" or fiction. The second problem was, in what emotional situation the patient is and how can we help or should we help her or him.

First Idea We combined fiction and emotions and came up with a game that can be seen as a DI-HULK and anti Katamari[5] game. It starts with the patient being very aggressive, also because of the loss of her hand, and she is going be become less and less aggressive to control herself and maybe being helpful at the end. We want to give her a bludgeon at the beginning instead of a prosthesis/hand. The longer she plays the calmer she gets. While getting calmer more and more wooden parts are falling from the bludgeon until it will look like a real hand. The player is also able to handle more and more complex things while playing.

Hand and bludgeon power (create bow between them)

- Start Bludgeon
  - huge like a planet
  - destroy planets
  - bludgeon arm
- End Hand (DI-Hulk)
  - Nice
  - Helpful
  - complex
  - small
  - help others

[5]Katamari Video `http://www.youtube.com/watch?v=aH2dbfVfurM`

Interview with Anna Felnhofer and Oswald D. Kothgassner, 2012 Nov. 15th

I met Mag. Anna Felnhofer[6] and Mag. Oswald D. Kothgassner[7], both Managing Director of the Virtual Reality Laboratory at the University of Vienna, to discuss my idea and they helped me to understand the state of depression and trauma a little better.

I started to tell them about the game idea and wanted to know what would be a good idea and what would be is a bad idea. First of all they said it is possible that the patient rejects the game. Not all patients, especially when in therapy, do want to learn how to work within a virtual reality. It is hard enough for them to handle the loss. The Interviewees meant it is important to ask the therapist whether the patient is willing or can handle and is ready to work with a computer.

The next point was the possible dangerous factors of the virtual reality, especially if it is a fully immersive virtual reality. They meant, it is very important to take care of the information transported in the game. It is possible to create a new trauma if the patient is exposed to a scene in which he or she was while losing a limb. Furthermore, trauma patients do have a very high suicide potential and therefore it is very important to know if the patient is ready for the virtual reality or not.

The last point was the question about differences between man and woman. I told them about the game play where the patient can get rid of his or her aggression by destroying objects. They meant it is a very male like view to calm down by destroying objects. In general (not always) man and woman act differently when they are confronted to something like a loss of one limb.

To conclude, the therapist should be able to control the context of the game and should be able to use the game as a tool but not as its replacement. Whether the therapist thinks it is better for the patient to destroy objects or to play with those objects. The therapist must always be the one who can control the situation.

Interview with Christian Schönauer, 2013 Feb. 21st

I met Dipl.-Ing. Christian Schönauer[8] and we tried out the game in the virtual reality room of the IMS. He played the game for a while and gave me feedback on what to change.

After playing for a while, he mentioned several improvements on the person controller. First, it should be possible to look around 360 degrees and to walk forwards and backwards. If the player uses a tracking device on his or her head it would also be possible to look up and down. Second, the rumbling for the giant should be automatically adjusted. Depending on the size of the screen the rumbling can be very distracting especially on a big screen. Finally, the game character should be visible on some point, especially when the player starts as a giant. It is just easier to identify and understand the gameplay when the player sees that he or she is a giant.

When asked for the game interactions he said that the game needs more feedback. First, the trees should fall apart in the direction the player destroys them. Second, the player should get a feedback when a tree stops burning. Finally, the sun should stay in a position where all objects

[6] http://ppcms.univie.ac.at/index.php?id=2909

[7] http://ppcms.univie.ac.at/index.php?id=2692

[8] `https://www.ims.tuwien.ac.at/people/christian-schonauer`

create a long and clear shadow. In the current situation, it is hard to distinguish how deep an object is displayed in the scene.

For the overall feedback, he said the showcase needs more gaming character. More challenges and achievements are needed as well for a funny and sustainable game.

Interview with Manuel Sprung, 2013 Mar. 12th

I met Univ.-Prof. Mag. Dr. Manuel Sprung[9], member of the "Institut für Klinische, Psychologische und Differentielle Psychologie" at the University of Vienna. In the beginning of the interview, I showed him my showcase and talked about my master thesis. My intention was to get an expert's feedback for future work.

The first point he mentioned was that he is positively impressed that the game includes the psychological situation of the patient. He said that it is quite common to focus only on physiological rehabilitation but in most cases, patients with an amputation also have psychological issues. The main reason for the lack of attention for psychological distress probably lies in the Austrian society where it is quite uncommon to talk about psychological problems. If such was to be attested most of the people would not admit to it.

I asked him about the importance of therapists because Ms. Felnhofer and Mr. Kothgassner (see Section 5.6) said it is not possible to help patients with a video game without a leading therapist. Mr. Sprung replied that he is sure it can work without therapists but not for all patients. He said the psychological situation of trauma patients has a normal distribution[10]. The first quantile are patients who can easily handle the loss and no psychological problem can be found. The last quantile are patients with a very high risk of a psychological problem. But the middle or center quantile are patients between a very high risk and no risk. He said video games could help patients in the center not to become high risk patients and he thinks that this is possible without an ongoing monitoring of a therapist.

One way to deal with the psychological situation is to create a narrative that changes with the player. His idea was to create many small story parts which create together a unique story for every patient. He mentioned two reasons why he thinks this is a good idea. First, it is very important for the patients to find a way to address their own problems. In many cases, patients do not want to think or talk about their own problems, but as long as they repress their situation they will not be able to handle it. Second, the story created by the patient and the computer gathers feedback information for the therapist. The latter can find out in what stage the patient is and if he or she needs a deeper therapy or psychological treatments.

I mentioned that our idea was that the patient can start to play as soon as possible after the amputation. He said that it was a bad idea to start earlier than one week after the operation. The reason for that is that the patient should not be confronted with the accident within one week. After that week, it is better to work and confront the patient with the happenings. This process is called debriefing. That was a practice used by the American Army in World War II and in other wars but studies showed that the psychological situation got worse.

[9] http://medienportal.univie.ac.at/uniview/professuren/detailansicht/archiv/2011/october/artikel/univ-prof-mag-dr-manuel-sprung

[10] http://en.wikipedia.org/wiki/Normal_distribution

Furthermore, I asked him what he thinks about multiplayer games and if it is a good or bad idea to create one. The reason for that question was that out of my general feeling it would make sense to work together with another person who has similar problems. He said it could be a good idea if patients only want to work on their physiological situation but might not be ideal for their psychological situation. The reason is that depression or bad mood is "contagious". If one person is in a bad state of mind the other person is likely to get it too. Peer groups are therefore not a good tool to overcome the psychological problems that an amputation has caused a patient.

On the question what to change in the game he said the game could be more visually appealing at the beginning. The reason is simply that he thinks it is funnier to start a game that is nice from the beginning on.

CHAPTER 6

Conclusion and Future Work

The goal of the thesis was to create a positive impact showcase game for the VR environment created by the IMS. To do so, the thesis describes all information needed, for a computer scientist, to create a rehabilitation game for people who had an amputation. The thesis itself is divided into four main chapters.

In the first, chapter the thesis gives general information about the amputation process, types of prosthesis, psychological and physiological rehabilitation and the influence of virtual reality in health care. In most cases an amputation takes place after an accident. The patients are all of a sudden in a situation where they have to handle a lot of psychological and physiological distress. Before the patient can start with the physiological rehabilitation the wound must heal first. Depending on the patient's situation, the healing process will take between six to eight weeks. During the conventional healing process a perfectly shaped stump for the socket, which is the connection to the prosthesis, is created. With the help of the VR environment, the patient is able to start the training process from the first week on. The next part describes different types of prosthesis from cosmetic prosthesis to functional prosthesis. A closer look is than taken on myoelectrical interfaces and TRM. Prosthesis with myoelectrical interfaces are that kind of prosthesis the VR was originally designed for. To close up, the influence of virtual reality in particular for rehabilitation is discussed. A fully immersive VR can have a large influence on the patient's psychological situation especially when the patient has the feeling he or she is literally in the VR. This effect is called presence. When designing such a system the designer must be very careful not to create more harm than to repair on the patient's psychological situation.

The next chapter gives an overview of game theories and what is needed to understand games. The first part is about the difference between game and play. Those two words bring many similar associations with it but have two different meanings. Play, on the one hand, is the act itself. Activities like football or rolling on the floor are considered as play. Games, on the other hand, are collections of rules in which people can play. The importance of play is that it can be found in many species not only in humans and it has a fundamental impact on how to explore and understand the world. The second part describes the game fundamentals: systems, meaningful play and the magic circle. A system describes a list of parameters which form a

complex whole. By changing one parameter in a system, it influences all other parameters. This action in the context of game/play is known as meaningful play. For instance, one player loses a figure in a chess match; it will have an immediate impact on the whole game. The last part gives a general overview of motivation. Motivation is a core principle for a person to start playing a game and to stay with the game. Two different types of motivation are known: the intrinsic and the extrinsic one. The intrinsic motivation comes from the "inside" of person. That means a person wants to take an action because he or she likes it or just to feel happier and more satisfied. The extrinsic motivation comes from the "outside" of a person and can be triggered by a positive reinforcement like sweets or by a negative reinforcement like a bad mark. In general, the intrinsic motivation is always the better choice.

The third chapter provides the reader with a list of five different game types user for the showcase. The first type describes the field of serious games. Serious games are created to influence the player. They are used for training in health care or for marketing reasons. Other games like Ludwig are used for educational purposes. The main difference between other game types is the game mechanics. The game mechanics for serious games are adjusted for a special purpose. On the other hand, the second game type called positive impact game will not infringe the game mechanics. It can be seen as a meta definition for games and the idea is that every game should have a positive impact on the player. A game designer needs to be allowed to create any game mechanics that suites the game but the story of the game, the interaction with game world, and the characters in the game should create a positive impact on the players "real world" life. The third game type is called exergame. Exergames are games where the player is forced to move the whole body. The idea is to encourage the player to more movement. Those types of games became highly popular with the Nintendo Wii and its different types of motion controllers. Not only the possibility to combine sport with video games inside the players four walls but also the simplicity to understand gross motor interactions made these types of game so popular. The fourth type are rehabilitation games which are especially interesting for the thesis. Rehabilitation games are focused on physiological or psychological rehabilitation. Games are a complement to rehabilitation. While rehabilitation itself might be repeating and boring, a game is motivating and exciting. Rehabilitation games try to encourage the patient for rehabilitation which has a direct input on the healing process. The last game types described in this chapter are art games. Art games are games where the focus is set on the feeling. While playing an art game the colors and the game world are creating a world that "just fits". An art game is not easy to describe, it is like an unusual experience a player has while playing.

The last chapter describes the game development process and the final showcase. For the game development process interviews, design sessions and rapid prototyping were used. These three types of impact led to a rails game in which the player starts as an Hulk like figure, angry and big, and ends as a calm and tiny player. On the way to the final showcase different types of possible hands where introduced. These hands are called magic hands and every magic hand gives the player a special magic power to solve a problem in the game. The idea is that those magic hands are getting more and more complex which keeps the player interested to go on because it is neither too boring and simple nor too hard. In the final showcase only two types of magic hands, the destroy hand and the fountain hand were used. The game itself is divided into four parts. The first part is called the *death* part. The world surrounding the player is full of fire,

dead trees and lava. The first quest is to destroy all the dead trees. The second part is called the *help* part. In this part the magic hand transforms into a fountain hand and the player must wipe out burning trees to help them. In the third part, called *create life*, dead trees must be watered to create new life. The final part is called *enjoy* and it lets the player enjoy a beautiful oasis. Altogether, the game tries to work with the patient's psychological situation by reflecting the game world on his or her situation and it tries to have a positive impact on the patient's ability to control the myosensor (see Section 2.1) respectively the prosthesis.

6.1 Future Work and Problems

To create some incentives for future game developments that are based on this thesis, the following section is separated into feedback-, gameplay-, story- and technical improvements as well as ideas for mini games.

In the future, feedback within the game should be improved in several ways. First, the instant feedback when destroying a tree or wiping out a fire. When hitting a tree, the physically correct parts of the tree should fall off with the right speed. The player should see the difference of the force when hitting a tree. When wiping out a fire, a special sound could appear to indicate how much water is left for a complete wipe out. Second, the rumbling of the giant needs to be adjusted for different screen sizes, preferable automatically. Third, a user profile should be created. This is not only important in order to start from the last save point, it can also give a feedback progress and improvements. Furthermore, indications about achievements collected while playing and comparing them between other players would be possible.

To improve the gameplay, every action needs to have a meaning for the game world/system. For example, the player puts a rock into a floating river. The river stops to float and the oasis depending on the water start to get dry. Furthermore, every action taken in the past should be preserved in the future. For instance, after the player destroyed some trees, these trees should not get reinstantiated after the player turns around. While developing the showcase, the question of a multiplayer game came across. The idea that two patients with the same problem work together sounded interesting. But while interviewing Manuel Sprung (see Section 5.6) the same question was asked and he said it might not be a good when working with patients who have psychological issues. The problem is that the one person who is in a bad mood easily effects the mood of the other person. This would be counterproductive.

To make the game as flexible as possible, many different story parts should be created which can be rearranged freely. The game should have the potential to dynamically change these story parts to create a new story line. Sprung (see Section 5.6) talked about two reasons for a dynamic story. First, every patient is in a different situation and in many cases not able to talk about his or her problems. A dynamic story could be a way for the patient to express him- or herself. This can happen intentionally or unintentionally. Second, if the patient changes the story unintentionally it could help the therapist to understand the patient in a better way, especially when he or she does not want to talk about the problems. The story could be seen as a way to express feelings.

To improve the players flexibility in walking and interacting the showcase needs to get connected with the virtual reality created at the IMS. Especially a fully 360 degree turn and the possibility to look up and down need to be implemented. A next step could be the creation of a

character that can run around freely in the game world. The current state is that the character is connected with an invisible road that he or she cannot leave. When connected with the VR the effects of a fully immersive VR combined with a HMD need be studied (see Section 2.4).

At the end of this thesis, some future mini game ideas are presented.

Whac-A-Mole Whac-A-Mole[1] is a classic arcade game where the player needs to hit moles popping up overground. This could be used as a simple but challenging game to improve the players reaction and to teach him or her basic movements with the magic hand.

Tower of Hanoi Tower of Hanoi[2] is originally a mathematics game where one tower is divided into finite different sized parts that need to be moved on another place. The only rule is that a bigger part is not allowed to be put on a smaller part. This game has two benefits. First, every part has a different size which forces the patient to learn how to open the prosthesis withing different stations. Second, the part count can be arbitrarily changed which gives the patient the possibility to improve every time he or she plays.

The helping Apple The idea is to collect apples from a high tree to help hungry people. This has two benefits. First, the patient learns how to grasp a high hanging object and second, the patient can help someone with his new hand. It is also possible to add a counter for this game.

Balance a Ball The task is to balance a ball on a plate. The level of difficulty can be changed with the count of balls, the size of the balls and the shape of the plate.

All in all, to create an exciting and sustainable game out of the showcase, the most important part is to collaborate with game designers for a meaningful and exciting game, authors for an interesting and colored story, physiologists for the right exercises and psychologists for the right situations.

[1] `http://en.wikipedia.org/wiki/Whac-A-Mole`
[2] `http://en.wikipedia.org/wiki/Tower_of_Hanoi`

List of Acronyms

VR Virtual Reality

HMD Head Mounted Display

DoF Degrees of Freedom

DMC Dynamic Mode Control

EMG Electromyography

TRM Targeted Muscle Reinnervation

ICF International Classification of Functioning, Disability and Health

ADL Activities of Daily Diving

PTSD Post-traumatic stress disorder

IMS Interactive Media Systems

PAOD Peripheral Artery Occlusive Disease

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