Serious Game for Stroke Rehabilitation on the HTC Vive

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Introduction

This project came to life from a collaboration between revalidatiecentrum the Hoogstraat and Philips Research Eindhoven. It entails the creation of a serious game in Virtual Reality to assist in stroke rehabilitation, with particular attention to cognitive aspects of the patient's issues. Hence, a game was designed and created in which the patients were to perform sets rehabilitative movements in a virtual environment that was controlled by the HTC Vive.

Motivation

When looking towards the future of healthcare there are many fields to explore. Be it robotic surgery, synthetic organs or cognitive mapping of the brain, healthcare is one of the most interesting fields for scientists to work in as progression directly contributes to the wellbeing of humanity. The most cutting edge of research saves lives every day. There are however more understated fields where research can aid man's wellbeing. One of these fields is rehabilitation.

After serious injury there is often a process of recovery required that involves regular and repetitive exercises to regain mobility and coaching to learn to work with newfound limitations. This process can be very taxing on the patients involved in them and there is little to speed it up. What can be done with various modern techniques is make it easier for the patients. Addressing the issues that may be roadblocks in their performing the exercises, or simply alleviating some of the mental stress is a worthwhile topic for research.

Serious games focus on enhancing tasks by adding elements of enjoyment and stimuli that are able to focus attention amongst other things. Their particular combination of entertainment techniques with practical tasks makes them immensely fascinating. Being able to provide someone with the motivation to perform tasks that can remind them of pain that they have gone through or that cause them discomfort is worthwhile.

The fun that games can bring is more than just fun. A smile on someone's face is a gift, especially when no one has seen it in a long time. Fun can create courage and give strength. Hence this project aims to do just that.

With the use of the modern technique of Virtual Reality, that can carry away a person from whatever situation they are in a serious game will be built to aid those stuck in a rehabilitative program to recover from a stroke. This game will aid their recovery process by providing elements of fun to help overcome cognitive limitations so they will be able to focus on physical rehabilitation.

Goal

This project envisions the creation of a user-friendly product in the form of a serious game for the HTC Vive that assists stroke patients with rehabilitation, in particular focus on enhancing the player's ability to concentrate. To come to this product a prototype will be developed under the supervision of Philips and tested with Hoogstraat Revalidatiecentrum.

The project will be deemed a success if by the end of the allocated period the tested product gives indication of enhancing player concentration and is deemed interesting enough to continue by experts.

Analysis

A thorough analysis of the circumstances is in order before considering a design to ensure proper use of techniques, confirm user requirements, and check design demands. To achieve that the following chapter will first cover research done into present projects concerning the use of serious games and virtual reality for stroke rehabilitation. The users, both stroke patients and therapists treating them, will be addressed. Then the capabilities and attributes of the HTC Vive will be discussed. Finally the software basics will be briefly assessed before assembling a list of requirements out of these various analyses.

State of the Art

Virtual Reality has been used in stroke rehabilitation research on multiple occasions before. It is still an unconventional and new tool. Next to that there are many different ways of using Virtual Reality. So far most research has worked with a projected Virtual Reality, a screen showing the virtual space, over using a head mounted device to allow full immersion. In comparison to the past, serious games have been used more and their benefits have proven to be clearer. There are three mayor areas where serious games have shown to be applicable on stroke recovery. Enjoyment, Concentration and Facilitation which will all be addressed.

Enjoyment

Key to making a serious game for stroke rehabilitation enjoyable for the patients is balancing the different elements that come into play when balancing play, where the greatest focus can be put on providing positive feedback, stimulus management, and setting the difficulty level just right. The enjoyment of a game can be very beneficial in enhancing engagement with the game, allowing the users to focus better on the task they are presented with [1]. Especially for people recovering from a stroke, who have just seen their entire life changed by the traumatic event, having an activity to look forward during their day is valuable, in particular when this also concerns their recovery [6].

What participants then need to be provided with is an experience tailored to their needs. Not every commercially available game is appropriate, but there are game design principles that perfectly correlate to the needs of this target group. The importance of making meaningful decisions in personal empowerment and feeling of purpose during the game has been used for years in commercial games. Trials have shown that for stroke patients this strongly carries on and patients playing games with these qualities appreciate them [7]. This empowerment also is achieved by overcoming challenge. Many modern games have received praise for having a very high difficulty and not taking pity on the player, as this increases satisfaction when progressing. This is different for rehabilitation games. The people playing these games are playing to improve an ability that they are confronted with in daily life on a regular basis. Getting stumped on an activity is therefore highly demotivating and confrontational. That is not to say that rehabilitation games should have very low difficulty, but ability must be the limiting factor in the difficulty [1]. This balance of allowing difficulty to be led by ability allows for a game that can take players to their limit, but not continuously confront them with their disability.

In light of the previous point it is possible to recognise that feedback on their performance seems to be very encouraging to the players. Positive feedback, which means awarding points for hitting targets or hearing audio cues when having solved a puzzle, appears to be a very appropriate approach for stroke patients as it is not very confrontational [2]. Contradictory however is the fact that cooperative play was a highly appreciated feature in several instances of previous research [4], but different from artificial enemies, human opponents can also draw out the very best of people and be a great source of

encouragement. Whereas this is an interesting opportunity in games and even in rehabilitation games, it has a strong focus on extrinsic motivation. In rehabilitation intrinsic motivation is assumed, but may be an equally viable opportunity. That assumption can be backed up by patient's appreciation of good story and companion characters [9]. While increasing extrinsic motivation with positive feedback and cooperative play is definitely a viable option, intrinsic motivation, such as curiosity through story exploration, should definitely not be dismissed.

Facilitation

While a serious game is not capable of making the exercises a patient has to perform easier, it can support execution of the motions by creating an environment that helps the patients understand their movement better. No statistically significant improvements to the rehabilitation therapy have been made by serious games thus far, but it has been confirmed that there are no drawbacks to the use of serious games to replace part of the repetitive exercises [3]. The benefits of serious gaming therefore need to be found in other areas such as the enjoyment. There are, however, elements that can be applied in game that make it easier to connect the actions in game to the actions out of the game, which is particularly important in virtual reality, which will be addressed later. The amount of feedback that a serious game can give on the execution of the exercises supports a more direct and independent understanding of the exercise [2]. This allows for less direct involvement from a physician and a greater understanding from the patient in general. So, while not making the actions of the patients easier, the environment they perform it in can definitely facilitate the rehabilitation process through encouragement or greater independence.

The virtual space itself can also be a great support by allowing a patient to experiment with physics or their limbs inside this safe space and later translating that to real space. The advantage of the usage of a virtual space here is the fact that there is no need for real physical objects to interact with. Controllers are often lighter and easier to hold than the real object patients are required to handle. The use of physics engines in serious games allows players to interact with the physicality of the object in virtual space without the required strength and dexterity for handling the specific object. And proper use of physics engines in a simulated environment allows for easier translation from the virtual environment to the real plane [10]. This all makes virtual reality and serious gaming a very safe space. Especially when the game and space designers have utilised the ability to separate cognitive and physical task, which pose often the most difficult situations for those recovering from stroke [9]. So while not proven beneficial, the research addressed in [3] judged there to be room for improvement. A lot of the points where serious gaming can really provide an addition there was little research done to confirm results, which is a waste. In particular the separation of activities and handling of real life objects in virtual space, appear to be very promising areas of study in serious games facilitation rehabilitation for stroke patients.

Concentration

The concentration problems, that are common among people recovering from a stroke, can be overcome with various techniques that are largely ado with limitation of stimuli. For example, presenting the player with a cognitive challenge can cause engagement with the game to spike [5]. However, it should be kept in mind that while dealing with concentration problems this would probably be best kept to separate challenges and not an overarching presence. This is similar for audio-visual cues that can be utilised to direct attention in the game very strongly [9]. In small amounts, this, in combination with clear goals, support engagement and attention of the players [6]. There is however a

delicate balance, as overstimulation is a very real threat that can cause a great deal of trouble to the player. Fortunately stimuli and attention can be guided by assuring only one cue can occur at a time and setting a time delay between cues.

The design of the game in general is crucial to get right to allow the player to be able to concentrate on the game at all. Proper cues, challenges, pacing and feedback are necessary to be able to keep the user engaged [7]. If you make a gaming session too long and the user might get over-exhausted, which will negatively influence their experience with the game. Pacing is crucial in games in general, but for someone recovering from a stroke the pressure of time can overly confront them with the fact they might find a task hard. In the design there are many elements to balance which will all be reflected in the perceived difficulty. The perceived difficulty should present a challenge that might seem hard, but can be overcome with present abilities. With overcoming challenges the player can build their self-confidence and familiarity with the different actions they used to be able to perform easily. Having this confidence and familiarity makes it easier to immerse into the game and can help the execution of tasks and general ability to concentrate on the game [11].

Virtual Reality

Virtual reality has been mentioned previously and has the potential of becoming the next generation safe environment for recovery training because of its adaptability within a small space. Serious games have shown to be something people are interested in, but virtual reality can add motivation, engagement and performance due to immersion in virtual reality [1]. In particular real life scenarios have proven to be excellent motivators as people can find their confidence in performing every day actions in the virtual space. The environment can be fully controlled and any situation could be simulated under the supervision of a physician. This also extends beyond the reach of conventional situations where various challenges can be presented to allow patients to try something out in the virtual space before taking their newfound knowledge or skill into the real space.

This one to one relatedness of virtual space to real space can also be a great aid in movement and limb awareness for those recovering from stroke [10]. Feedback on movement, exercises and position can be given directly mapped onto the arm that can be simulated in virtual space. This tracking of the limb can increase control and awareness of how the body can and cannot yet move [7], which is vital to the recovery process. Whereas it has not been proven to have direct consequences [3], the absence of contrary evidence and large studies from game design orientation may suggest an unexplored area in recovery support from virtual space. So while being very careful to consider the safety of the patients the increased limb awareness that can be provided by virtual reality is a strong contender to explore in rehabilitation of stroke patients.

Conclusion

It was possible to extract several aspects in serious games that can be applied to improve rehabilitation for stroke patients. All three sub questions could be answered with the point of discussion that although useful this list is based of articles that have been concluded to not be statistically significant and therefore need further research to get further confirmation. There are definitely serious game designs that have been tested on various forms of the target group of stroke patients, but the projects so far seem very scattered and do not have a focus on one of the categories analysed. Whereas enjoyment of rehabilitation games has been a largely researched area with a few interesting elements popping up, the games were very similar and very strongly focused on masking the exercises. The games could not make

exercises easier for those playing them. There are a few game design standpoints that have been identified to be detrimental for stroke patients, which is valuable information. With this information, it is possible to assure minimum discomfort when designing a new game. Overcoming concentration problems seems to have been a slight afterthought in most instances. It could be very much worth it to explore possibilities in this area, especially with the connection between engagement and enjoyment. Finally, virtual reality as presently available in modern technologies could be explored to far greater depths.

With present information a framework could be set up to outline restrictions for a game designer to work in, not being fully briefed on the main issues that arise when dealing with stroke patients. The following list of usable game design aspects can be concluded:

- Games should provide challenge
- Games shouldn't confront patients with their limitations
- Games should empower the player
- Games can support experimentation
- Games can give direct movement feedback
- Games should properly distribute stimuli to keep attention focussed
- Games should be designed linearly with a cohesive non-branching story

This framework, while being a start, doesn't paint the full picture, and it would need an attending physician's approval. However, it could certainly be worth exploring other restrictions on serious games for rehabilitation as it could open up the way into commercial domain for gaming and invite new visions on helping recovery. Future research should certainly focus on confirming a many of the indications that can be found in many papers so that a scientific base can be created for rehabilitation games. Serious games are a viable option to improve rehabilitation for stroke patients by not addressing the difficult task that cannot be changed, but by creating a stimulating, safe and encouraging environment that allows them to reach the limits of their ability and enjoy every small victory.

The users

In the use of a serious game for recovery, there are two user groups involved; the therapists who treat the patients, who are the ones to introduce the system, possibly operate it and decide the exercise regimen for a patient and the patients themselves, who will use the system and interact with it the most. Both of these parties have very different, but equally important, demands of the system's functionality and operating.

Stroke Patients

A stroke is a type of cerebral accident where blood supply to the brain or a section of it, was suddenly cut off. The cause of the stroke is often a determining factor in the type of stroke, recovery degree and period and the damage that was suffered. The lack of blood causes damage to neurons that die off or lose functionality. Since it is still unclear how exactly the brain works scientists have so far been unable to determine what exactly happens during this.

A stroke can be a bleeding or a blocking, but can also be categorised by the course they progress through. A Transient Ischemic Attack is a short-term neurological shutdown where the patient fully recovers within 24 hours. A Reversible Ischemic Neurological Deficit is similar, but has a longer recovery period. A Progressive Stroke has symptoms getting increasingly worse over time until the patient dies.

Finally a Completed Stroke has the patient reach a stable clinical condition, but be left with symptoms that are sometimes possible to overcome, but never assuredly. The Completed Stroke is the one that this project will be focussing on, as this is where the intense therapy is required.

The symptoms that follow the stroke vary strongly. It is therefore that it is usually said that there is no typical case of a stroke. Symptoms may include whole or partial paralysis on one or both sides of the body, loss of vision, speech impairment, concentration problems, personality changes and more. It is usually unclear how much a person can recover from these symptoms, but there is urgency to start the recovery process as most improvement can be seen in the first weeks.

As previously mentioned stroke patients have suffered brain damage leaving them often with problems such as the inability to retain attention, speech and perception impairment and sudden headaches. That is aside from the physical repercussions they have to overcome and the fact that the trauma of the stroke and recovery from it leaves many depressed and unable to readjust. Because of this stroke patients need to be regarded as a protected target group.

This has consequences for the different techniques that can be used in the game design elements. Whereas addictive mobile games have plenty of useful techniques for retaining attention, considerable care when consulting these methods should be taken.

Furthermore, the amount of both mental and physical stress they are under can interfere with their recovery process. As this is only adverse to the intended purpose of the design, this situation must be avoided at all costs. The design may not harm the patients or their recovery in any whichever way.

Therapists

For rehabilitation after a stroke there are various different aspects that people may need help with in their recovery. Depending on where in the brain the stroke occurred it may affect speech, perception, personality, manoeuvrability or something entirely different. There is no such a thing as a typical stroke, as stated before, so all patients may see different therapists. There are two that are in particular important concerning this research.

Physiotherapists help patients with regaining mobility. They help manage exercise regimens, can help with barriers patients hit in their movement and assist with regaining freedom of movement. It is important for them to be involved with the system's operation in the early stages as the game aims to support the exercise regimen. Aside from that, they need to be consulted to ensure that patients are physically able to use the system and possibly aid them in tasks in early stages of gameplay.

Psychologists support patients in diagnosis of their mental disabilities and help restructure a view on life that will help them get back into daily habits. Their clear insight on the patients cognitive abilities is crucial for detecting possible hypersensitivities that a patient may not be able to voice. They need to be involved with the system to ensure responsible decision making in proposing the system to the patients and assist users in understanding what they are getting into.

They are experts in movement and cognitive functioning and have to keep up with new discovery of treatments and technology. Of course, the development that is always ongoing is a lot to keep up with. Expecting a physiotherapist to also function as a computer scientist in order to operate a virtual reality

device that was intended to make things easier on them and their patients is unreasonable. Their demand of the system, while simple, is very important.

The system needs to be easily operable by those supporting the patient.

The System

After being delayed slightly the HTC Vive, a collaboration between HTC and Valve corporation, was released on April 5th 2016. Since then it has proven to be the preferred choice for software developers, according to techradar as of june 6th 2017, and a reliable tool for experiencing VR.

In all, the HTC Vive is a combination of a software and hardware product.

Hardware

The HTC Vive is made up of several hardware components; two controllers, two lighthouses, and the head-mounted display (HMD). These components all communicate with each other, which the HMD passes on through the only connection to the PC where the software takes over.

The controllers, see figure 1, contain a lot of sensors for registering movement, relative location, orientation, rotation and more. Aside from that a controller has several buttons. A trigger(7), squeeze button(8), touchpad(2), menu button(1) and system button(3). The information from the trigger, squeeze button and touchpad are accessible via the steam software. The controllers are wireless and are not required for the system to function.

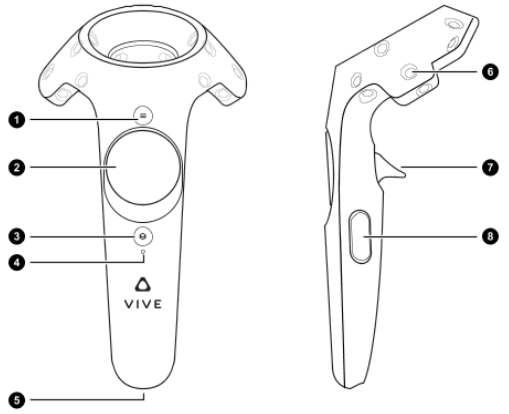


*Figure SEQ Figure * ARABIC 2: Schematic HTC Vive Controller*

The lighthouses are staged cameras that detect the controllers and HMD within the game space and communicate this back to each device so it can relate its own position in the game space. They require line of sight to the tracked objects while calibrating, but do not continuously require it during play. For a standing gameplay session where you want to walk around it's advised to use both cameras, but it is not required, for seated tracking it is also possible to use just one of the lighthouses.

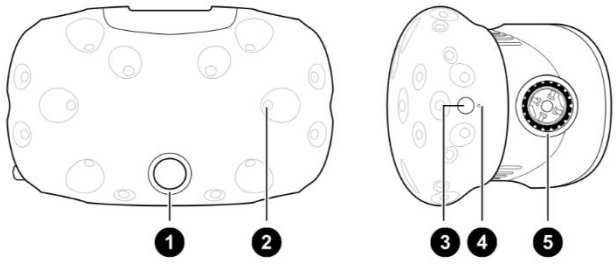


*Figure SEQ Figure * ARABIC 3: Schematic HTC Vive HMD*

The HMD is the only device attached to the PC. The HMD had two screens behind convex lenses, each with a display resolution of 1080x1200. It is possible to place the device over glasses and adjust distance of the lenses to each other and your eyes. The headset is also equipped with a lot of sensors for the same purpose as the controllers, but add in a few more. The HMD is strapped to the user's head with elastic bands that have a Velcro attachment strip for easy adjustment. There are 2 bands over the side of the head and one over the top of the head for firm fixture.

Since March 2017 another device was added to the Vive's hardware setup. The trackers are add-ons with all the same sensors as the controllers, but no buttons. They are designed to be attached to an object you intent to track. Say a sword, or a tennis racket. They do not come in a standard Vive setup.

Software

To use the system the PC requires steam and the Steam VR app to be installed. This allows for a status screen showing all the connected devices. The system shows in this status screen when there are connectivity problems and if the controllers and lighthouses are active and seeing each other.

Not all software is accessible, but for easy developer use of the system Valve released the SteamVR plugin. This software allows for access to the controller and HMD outputs and visibility of the controllers. Next to that it also provides meshes for the controllers and manages predicted rendering of controller movement. The plugin, when used in the Unity engine, is a case of plug and play.

The engine

The engine that the game will be created in is the freeware application Unity. The used version will be Unity 5.5.*f as these are the most stable versions of Unity and are able to be converted to each other without much consequences. This is an open source gaming engine that uses object oriented programming languages, Javascript and C# in particular.

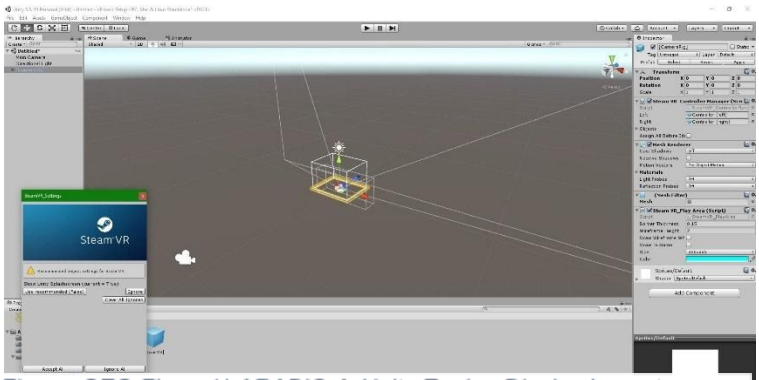


*Figure SEQ Figure * ARABIC 4: Unity Engine Display Layout*

"Unity Technologies offers a platform for creating beautiful and engaging 2D, 3D, VR, and AR games and apps. A powerful graphics engine and full-featured editor enable you to realize your creative vision fast, and deliver your content to virtually any media or device. You can easily connect to your audiences on PCs, consoles, the web, mobile devices, home entertainment systems, embedded systems, or head-mounted displays." – Unity Website

Design

The design request was for a game that could keep the attention of players during a session. This chapter will address the various phases of the design and the techniques applied to in order to design a system that would speak most to the user groups.

Design Demands

From the analysis phase, the assignment and additional research it was possible to deduce a few demands of the product. Additional research involved observation of various treatment groups at the Hoogstraat Centre for Revalidation and an interview with a physiotherapist involved with the project.

The project duration is 10 weeks.

To accommodate this period and the product demands of the two users groups, two MoSCow analyses were made.

MoSCoW analysis of game attributes required by patients

Must

- contain clear and short instructions
- be made up of meaningful actions
- have at least 4 different exercises of arm, shoulder, hand and head programmed
- have a reward system for completing an exercise
- recognise successful execution of set exercises

Should

- accommodate the execution of any useful exercise initiated by the patient
- have a reward system for completing the exercise set
- recognise successful execution of all programmed exercises

Could

- support outside/onlookers participation
- support tactile cues
- incorporate repetition of instructions

Would like

- to have a higher purpose to the game as a whole, so the sense of achievement is greater

MoSCoW analysis of game attributes required by physiotherapists

Must

- allow setting of the exercises
- be usable without prior knowledge
- allow insight in player in-game actions
- allow visual on player actions

Should

- show feedback of move execution (duration/accuracy)
- provide clear instructions of tasks

Could

- allow for impulse activation during play.

Would Like

- to support minimal play for most affected patients

Ideation

Game Type

During the ideation phase the types of games and their settings were mostly considered. There are many classic gaming genres to be considered. The demands are however, that the game must be realizable in Virtual Reality with the HTC Vive, and that the game needs to support the execution of rehabilitative movement.

The gaming types selected were the following:

Atmospheric walkabout

The focus of this type of game is removing the player to a different place so they are cognitively stimulated by a change of atmosphere and feel free to attempt new things. The game provides very limited stimuli and instead focusses on game space design to encourage the player to discover features of the environment themselves.

- Advantages: it speaks very much to elements outside rehabilitation, there are no time constraints, it has very different gaming feel which may speak to a broader target group and it is target age appropriate.
- Disadvantages: it is difficult to place exercises in and the whole situation does not have a goal to work towards.

Point-n-Click

A very popular style in the 90's point 'n click adventures set arcs of puzzle solving where the player has to go back and forth between different places to collect objects and use them to solve puzzles. They are very much story driven games and often use humour to keep the players enticed. With minimal interaction the only thing the player does is go to an object and click on it.

- Advantages: the games are very paced, they allow for story implementation, the movement to be implemented is very simple and natural and the game has room for very clear cues.
- Disadvantages: This game type requires cognitive challenge which could lead to less movement, the game cannot support all types of exercises and the game's goals are not always clear.

Mini-games

Usually presented in a collection mini-games focus on performing very few different actions per game but perfecting the execution of these by extensive repetition. Limited in context and causality, they lend themselves to excite players with scores bonuses and reactive effects.

- Advantages: they can be tailored for a specific movement, the games are short in duration and all games support repetition
- Disadvantages: Mini-games often hold stress elements and all motivation is extrinsic.

Escape Rooms

In their design a cognitive challenge, an escape room challenges the player to find sequences of puzzles to achieve a single goal within a limited space. They don not provide clear tasks to the players and instead invite exploration.

- Advantages: the games are strongly paced, they allow for story implementation, the movement to be implemented is very simple, the game has room for clear cues and the nature of the game provides inherent space limitation.
- Disadvantages: Escape rooms are long cognitive challenges, the games are hard to keep short, the game cannot support all types of exercises and the game's goals are not always clear.

Simulation

The purpose of a simulation is to provide a real environment in a virtual one to accommodate different execution of known actions. They can accommodate task execution, but have limited ability of providing a goal to work towards.

- Advantages: The game provides a direct real world translation, the players can perform known activities instead of having to figure them out, the game is very paced and there is room for clear cues
- Disadvantages: Players may be confronted with problems they already come across in daily life and get disheartened by it, the game cannot support all types of exercises and the game's goals are not always clear.

Game Space

To confirm the type of gamespace, 3 different locations were modelled in 3d and examined in Virtual Reality to test the effects that the space had on the player. The three different spaces were a kitchen setting, a greenhouse setting and a forest setting. They were chosen because of their difference in spaciousness towards the player and their ability to accommodate games.

To determine which setting was most appropriate, three people with VR experience were placed in all three different environments and asked what they thought of it. Their answers along with observations on their behaviour determined the opinion on the setting.

The Kitchen Setting:

While very inviting to interact with the gameplay elements, the space felt very confined as it had walls all around the floor space. Next to that there was an issue

with having the urge to lean on counters in virtual space that weren't there in real space, which creates a dangerous situation. The familiar setting immediately gave context to the situation, but it wasn't very interesting to be in the location

The Greenhouse Setting:

*Figure SEQ Figure * ARABIC 6: 3d modelled space Greenhouse Setting*

*Figure SEQ Figure * ARABIC 5: 3d modelled space Kitchen Setting*

The space was new and interesting which made the players slightly hesitant to interact at first, but they did go looking for things to do, after getting used to the space, with familiar objects that laid around. Due to the glass wall, the space felt safe and enclosed, but not confining or threatening. There was some issue with leaning on tables, but only minimal due to the absence of legs to the tables.

The Magical Garden Setting:

This space had limited objects to interact with, but players also didn't go look for them at all. They stood very still and kept looking around to the environment that was the most interesting about this game. The absence of limitations to the playing field made that people were hesitant to move about.

*Figure SEQ Figure * ARABIC 7: 3d modelled space Magical Garden Setting*

Game Actions

As a rehabilitative game the actions performed needed to correspond with the training regimen that the patients are subjected to themselves. There are several exercises that the physiotherapists of Hoogstraat assign their patients to aid with their recovery. These exercises are possible to be performed without the assistance of a therapist and are therefore suitable for practice in virtual space.

The exercises were extracted from two sources: "De Beroerte App" and "Snel in Beweging Oefengids Beroerte" both made by the Hoogstraat. These exercises were sorted by the rank of movability that was required. Additionally only moves that were deemed trackable in virtual space were selected. The focus was put on upper body rehabilitation, limiting the list further.

The following list of exercises remained:

All movements have a difficulty classification as follows.

(1) Suitable for severe impairment
(2) Suitable for much impairment
(3) Suitable for light impairment

Neck:

- Turn head left and right(1) (2)
- Angle head left and right(2)

Shoulders:

- Raise shoulders(1)
- Raise stretched arms(1)
- Raise stretched arms and reach(2)
- Move hands to forward left and move hands to forward right(2)

Arms:

- Move hands left and right over a surface (1) (2)
- Tilt folded hands left and right (2)
- Move folded hands forward across a surface (2)

Elbows:

- Bring hand to chest with both hands (1)
- Bend elbows (2)
- Raise stretched hands off of surface (2)

Wrists:

- Fold hands open (1)
- Turn folded hands forward and backward (2)
- Turn folded hands left and right (2)

Hands:

- Open and close a screwcap (1)
- Grab and hold an object (2)
- Touch nose, forehead, ear and shoulder (2)

Fingers:

- Crumple up a piece of paper (2)
- Folding movement (2)
- Pressing a small button (2)
- Squeezing with whole hand (3)

After examination of controller output there were a few more movements that were difficult to measure in virtual space due to orientation and space related output values.

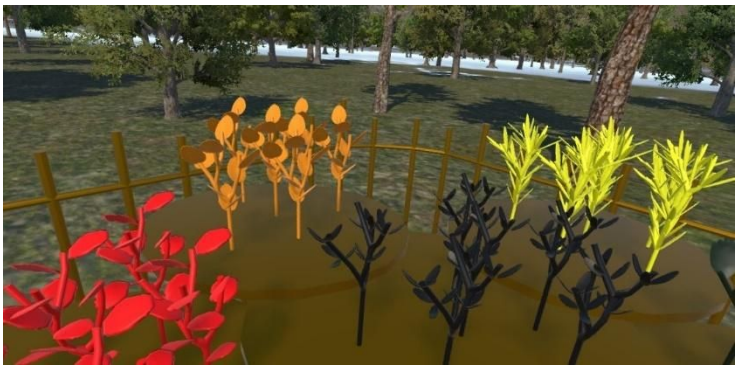
Hence 5 initial movements were selected to implement in initial stages:

1. Raise and lower stretched arms
2. Move hands to stomach and away from stomach
3. Make a circle motion on flat plane with both hands
4. Bring both hands to chest and back to level
5. Sweep arm to left, right and centre

Conceptualisation

Based on the demands, the selected movements, possible game spaces and requirements a suitable game concept was decided upon.

The game would take place in the previously described greenhouse setting with a light surreal touch to encourage care in the unfamiliar surroundings that should ensure there is no intent to lean on objects. The confinement of the greenhouse is natural, but not claustrophobic and ought to provide a suitable place for performing the exercises in. The decided movements are possible to be placed inside the context of an alchemy lab, which will be placed as game objects in the greenhouse.



The alchemy task context provides familiar actions in an unfamiliar context. This should assist with regaining natural movement, but not confront the users too much when they hit a roadblock as it is still an abstract task they are unable to perform. The game type for this is mini-games, where minor actions make-up a larger task and provide a goal to work towards. This allows for the greatest form of adaptability in tasks and difficulty.

During the game the player will trace movements in the virtual space over a path that is laid out as they start a movement. A task consists of several repetitions of an exercise, which will be made up of a set of movements. The player will be rewarded upon completing a movement, exercise and task. All feedback will be positive in nature.

The therapist will be able to see the patient move in real space as well as monitor their actions in the virtual space on the computer screen of the PC that the vive is hooked up to. In initial design they will be able to give a set of selected movements that can be performed in virtual space. The observing party will only have to start the application and not need to change any settings before play.

Realisation

The realisation of a prototype started on April 19th 2017. Agile Scrum was used to assist in planning. During the first 6 weeks this was in sprints of 2 weeks. After that 1 week sprints accommodated the progress better.

Movement Detection

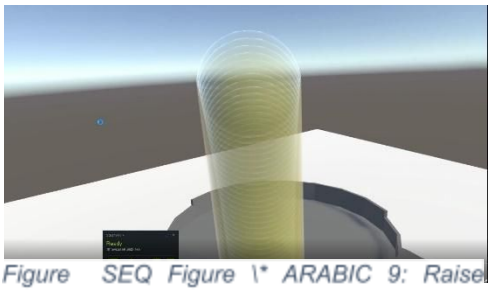


Figure SEQ Figure * ARABIC 9: Raise Movement indication gameplay screenshot

The core of the game was the ability to detect various exercises in virtual space and give the user a guideline to follow. The code that was able to detect this came in 3 classes. The MovementDetector class is the main component. It is assigned to the controller object in the Unity Game Scene to ensure that the moment that the controller is detected the game will start and put everything in the right place. Exercise is the class that controls the reading of the exercise information. Exercises consisted of Movements that were stored in the program and could be accessed by name. Each movement has a mathematical function describing the trajectory in 3d space relative to the player and controller

Upon initialisation MovementDetector will load a csv file with various exercises and store these. An exercise has a description of the components it is made up off, movement up and movement down for example, and the conditions to start an exercise, a location or direction of movement. The MovementDetector class, while awake checks with every call of the update function if any conditions are met. If that is the case the class CreateOrbs will set out a path of exactly 40 points that are on a section of the mathematical function that the describe the first movement. This path is visualised by orbs on the path so the user knows where it is, see figure 9 and 10.

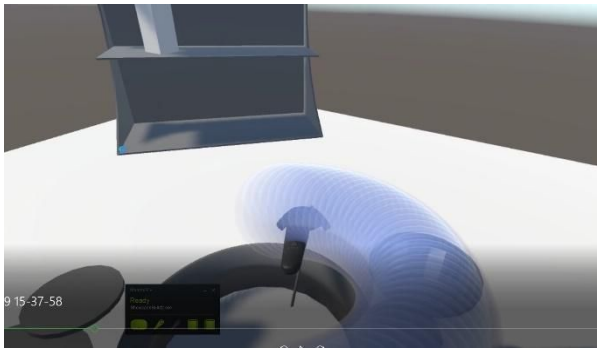


Figure SEQ Figure * ARABIC 10: Stir Movement indication gameplay screenshot

While the exercise is ongoing, on every call of the update function the distance of the controller to the path is measured. If that goes over the threshold, the movement is cancelled. If the distance to the final spot is within bounds the next movement will be started with functions in the Exercise class. Upon completing the exercise all paths will be removed. The player can perform as many repetitions of an exercise as they want as a new path will be generated whenever an exercise is started over.

*Clean scene images **

Environment

The game space is a terrain of grass and dirt with some mountains at the side and trees surrounding the play area. The area

will be restricted by a fence at approximately hip height that will be covered with 3d modelled vines. Inside the play area there are 4 work stations. One with a cauldron and cabinet, one with 5 different herb plantations, one with drawers and a last one that is presently out of order, but can be used in later levels. To keep an overview of tasks there will be a notice board with tasks that the player.

Gameplay direction

Figure SEQ Figure * ARABIC 11: Game Environment

In present project the focus was on getting the mechanics working and not a progression system that would incorporate an artificial agent to set suitable assignments for the patients. A system to give the patients tasks in real time from the computer that is running the game.

Figure SEQ Figure * ARABIC 12:Example task image

While the game is running there is a display on the computer that shows a non 3D display of what the player is seeing. Over this visual there is an overlay on which a few buttons were put that can be clicked with the mouse. On each of these buttons is a short description of the movements that are to be executed for the task. When the button is pressed, a script is called that creates a task object instance with an attached canvas that holds a list of exercises needed to be performed for the task. Every exercise is described with a name and an image of the location where the exercise is performed.

Figure SEQ Figure * ARABIC 13: Virtual Task Corkboard

On creation the task is placed randomly on a corkboard modelled in the virtual space, see figure 13. The player can choose to start a task by touching it with a controller. The task object will then attach to the controller so it can be read at all times and remind the player that they picked up the task. When having performed an exercise on the list it will be removed from the to do list and when all tasks have been performed correctly the object will disappear from the controller and be destroyed. A coloured light and sound will confirm to the player that a task has been completed correctly.

Intermediate User Tests

On June 6th and 7th 2017 intermediate user tests were performed with the system to give further direction to the realisation process in the last weeks. It helped prioritise functionalities. The tests were performed with twelve students at the University of Twente.

Setup

The test were performed at the University of Twente. The participants were all volunteers who had been told they would be testing an incomplete version of a Serious Game in Virtual Reality. Most participants had limited to no experience with Virtual Reality. All tests were performed in Dutch.

Before starting the tests the participants were given a short explanation on the HTC Vive, told that they would be using only one controller in their non-dominant hand and were assisted in ensuring optimal visibility with the HMD. They were also informed that things might not always react as they expected.

With no further instructions the game was then launched.

During their time in the game their movement and impulses were observed on the desktop display of the game and in real space. When users were unclear what to do they were given a short instruction to touch a table that would initiate the first gameplay action. When users were unclear on what to do with the gameplay action, they were instructed to try to follow the coloured line. When users were unsure why the line disappeared they were told that the vibration of the controller indicated them having performed a task correctly.

After having the users try out these gameplay elements they were asked 3 questions while still in Virtual Reality.:

1. How do you feel about the environment?
2. How do you feel in VR?
3. Do you have the tendency to lean on tables and/or put things on them?

The answers to these questions were noted and the users were given time to finish up in VR before being assisted in taking of the Virtual Reality Device. After their experience, an informal semi-structured interview took them through their experience.

1. Experience using the active(non-dominant) hand
2. Experience using the inactive(dominant) hand
3. Experience with the starting of the exercises
4. Experience with the performing of exercises
5. Experience with the completion of exercises
6. Other points that came up

Finally the user would be given context of the game and full explanation of what it was going to be doing and how it would function eventually. They would also be given room to ask questions about the project.

With that the test was over and their answers and actions would be denoted and processed.

Results

The Dutch transcription of the interview notes is in Appendix A.

Questions asked while in VR	
How do you feel about the environment?	**Keywords:** Confined(Opgesloten), Safe(Veilig), pretty(Mooi)
	The outward environment was appreciated but experienced as so vast that people needed the safety of the confined cage that was implemented. Because the bars reached till over their heads the cage was also experienced as confining.
How do you feel in VR?	**Keywords:** Hesitant(Aarzelend)
	The novelty of the device made that people were slightly hesitant to move around, but eventually got used to it.
Do you have the tendency to lean on tables and/or put things on them?	**Keywords:** No(Nee), table legs(tafelpoten)
	It was pointed out several times that the absence of legs on the table ensured that almost none of the players had issues with leaning on virtual tables.
Questions asked afterwards	
Experience using the active (non-dominant) hand	**Keywords: -**
	No particular comments were made about the handling with an inconvenienced hand.
Experience using the inactive (dominant) hand	**Keywords:** Adjusting(Gewenning)
	Initially most players intended to interact with the dominant hand that did not hold the controller, but due to only receiving feedback on use of the non-dominant hand that held the controller they adjusted fairly quickly as it helped focus on that hand.
Experience with the starting of exercises	**Keywords:** Confusing(Verwarrend), irregular(Inconsistent)
	There were several complications with starting the exercises as the colliders weren't exact along with the fact there were little to no indications of what players had to do.
Experience with the performing of exercises	**Keywords:** Fun(Leuk), colours(kleuren)
	Players indicated that it was fun to trace the arcs and that the colour change was a nice way to indicate transition.
Experience with the completion of exercises	**Keywords:** Chasing(Volgen), feedback(feedback)
	Several players indicated confusion upon completion and required a visual or auditory reward to have confirmation. Additionally there were some issues with new movements starting up after the last one was finished and getting increasingly close to the player, which caused discomfort.
Other points that came up	**Keywords: -**
	No particular common comments were made.

Discussion

The experiment ran smoothly. Twelve people, of whom most had limited to no experience in VR, were recruited for playtesting. Each of them spent approximately 10 minutes in Virtual Reality playtesting the game. The participating group was not large, but sufficiently large to display various opinions and have all essential points, which were also the ones eventually addressed, be brought up by multiple people.

No unforeseen complications occurred during playtesting. Before playtesting the game had to be converted to Unity 5.5.2 as that was the version available on the used desktop. This caused no issues with the game's functioning or display.

Observations from the players interaction with the game and their collective opinions allowed for a few clear points of improvement to be derived from their experience. However, as people differ in opinions, there were some points were opinions were divided. As they were never really mayor complaints, it was decided they would be ignored. This does mean that not the full spectrum of results were utilised.

Finally many of the participants were familiar to the game designer. Which means that a general positive attitude needs to be assumed towards the product and its use. For enjoyment the questions were hence deemed of less value than observations during the test session.

Conclusion

From these results the conclusion could be drawn that the game as present had some entertainment value, but needed some improvements in particular areas.

The following list was concluded:

1. Fix the colliders; in present state they respond too often which confuses the players. It is necessary to implement correct colliders to have a functioning and understandable game.
2. Adaptable table height; with the exercises focussing on the player's range of motion, they need to be able to perform the task in the best conditions. During playtesting, the tables were found too high for two players. Calibrating the table height for each individual player is necessary to implement for proper game functionality.
3. Add clearer indication for exercises; there were many players who needed guidance towards the tasks, as they did not know how to initiate exercises. With clearer indicators or instructions for the start of a task, the player can more independently play the game, which is necessary for continued immersion that supports the focus on the exercises.
4. Make clearer confirmation of exercise completion; once an exercise is completed the player needs to immediately know that they performed the exercise correctly to avoid confusion and the resulting disinterest. This can be done by providing more environmental feedback or by adding visual rewards.
5. Implement more rewards; all presently implemented positive feedback on the exercises does assist in player engagement and effort, but the game requires additional reward functions as several components are decidedly less enticing to players due to lack of reward. To have equal interest in the various movements, all exercises need to have the designed three layers of reward implemented.
6. Open up the game space limiting cage; the game space in the virtual world was given an arbitrary barrier to provide a continuous edge of the playing field. The present birdcage was

decent as it provided a feeling of safety, but felt lightly confining due to it going over the players' heads. In later iterations it is preferable to have the cage be some form of a fence, to make the player feel less confined.

7. Give the players tasks to perform; during the gameplay test there were many players that needed additional guidance to start performing actions as they were unsure of what to do. TO give those players a sense of purpose and direction the game should implement a system where the players receive tasks they can perform. A task consisting of doing a few exercises with a reward or a real consequence. This also should add a feeling of purpose and goals to the game that were also missing.
8. Implement a story; several players indicated they'd like to know what they were doing, why they were doing it and why this environment. A context for the game can be given in a story around the gameplay and space. This is not a vital improvement, but definitely something to be considered in the later runs of the game.

Additionally the game was proven stable and safe with no participants expressing any discomfort during their time in VR.

Reflection

The first seven points of the conclusion were successfully implemented after the tests. Custom colliders were built for various objects and the collision detection script was updated. The height of the game objects became a variable that was determined based on the height of the HMD at the game start. More logical handles were implemented to guide players towards interaction. Rewards and exercise completion feedback were added to clarify the completion of movements and exercises. The birdcage was cut off at roughly half a meter high and turned into an irregular garden fence to open up the environment slightly more. Finally a system was implemented that allowed a person supervising the system to input tasks on the virtual corkboard to give the player a clearer sense of direction.

Final User Tests

The final user tests for the project were performed on Monday 26th of June 2017 at Hoogstraat revalidatiecentrum with supervision of Joep Janssen. Joep Janssen had responsibility over the patients and selected those who were in suitable condition for testing. The tests had the purpose of determining if the research goal was achieved with the project.

Setup

The estimated time for a test was 20 minutes, which could vary by 10 ten minutes depending on player interest and energy of the player. The test consisted of two parts, the testing of the game, which took a maximum of fifteen minutes, and a short semi-structured interview to document the player's experiences. These tests were done with patients and therapists, with the therapists having an additional interview part to the tests. All patient tests were supervised by the patient's treating therapist to ensure the patient's safety.

The players received a brief introduction to the HTC Vive and the game and were assisted in donning the HMD. After this they could see the white start up environment of the HTC Vive. In this environment the controller was be handed to them and controller wrist strap was fastened around their wrist. The players were explained that they can walk around safely until they saw blue rostering in front of them. After that the game was started.

During play the player was assisted as necessary and asked to interact with the various objects that cause exercises the spring. The player was asked to explore every exercise at least once. After that a task was loaded by pressing a button on the desktop and the player was be asked to perform it. Next to performing the requested tasks the player was free to play with the elements as they saw fit.

The session was terminated when all tasks had been performed, when the patient indicated that they want the play session to be over, when it seemed necessary to stop the session for whatever reason, when the supervising therapist indicated it is necessary to stop, or when fifteen minutes had passed.

After the play session was terminated and the player was still up for it, an interview followed. The interviews were conducted in Dutch as this is the native language for the largest portion of players. The interview was structured with the following questions, the Dutch translation is added in brackets:

- Did you like this way of performing exercises (Vond je het leuk om op deze manier oefeningen uit te voeren)?
- What did you like about the game (Wat vond je fijn aan het spel)?
- What did you not like about the game (Wat vond je minder fijn aan het spel)?
- Did you manage to perform the exercises correctly (Lukte het om de oefeningen goed uit te voeren)?
- Was it clear what you had to do (Was het duidelijk wat je moest doen)?
- Do you have anything else you want to say (Heb je nog andere opmerkingen)?

For the playing therapists an additional explanation was given on the operation of the system and the possibilities of the system. They were then asked the following questions, a Dutch translation is added in brackets again:

- What do you think the system would be able to add for you (Wat denk de dat het systeem voor jou kan toevoegen)?
- What would you add to the system to make it more appropriate (Wat zou je aan het systeem toevoegen om het gepaster te maken)?

The player then got the chance to ask any questions they might have had about the product and the project as a whole.

After this the test was concluded.

Results

The full Dutch transcription of the interview answers is in Appendix B. Observations on play were only made on the patients as they are the intended target group for play.

Observations	
Patient 1	Wearing the HMD was slightly difficult with protective helmet. This made it difficult for the participant to move around, which, in combination with the inhibitions that come with the afflictions, caused very stiff and limited movement. Additionally there were some issues with the test for this patient, which will be discussed in the discussion section.
Patient 2	The player was very engaged with the game and exploring a lot of different exercises. They performed all exercises correctly, though didn't initially notice the backtracking of the close arc and opening drawers was required. Almost fell when looking under a table and tried to grab it for support. This was no issue as she was in sufficient physical condition to more freely.
Patient 3	The player was very focused on the game. They had difficulty moving around but did go to explore and attempt all the exercises with some encouragement. The player was known to have concentration issues, but seemed to be able to almost fully overcome this for performing the tasks in the game. The participant required help in moving around by holding the arm of the supervising physician. They were slightly afraid of stepping on the wire at first, but this became less as she was getting used to the device.

Interview	
Did you like this way of performing exercises?	**Keywords: *Fun(Leuk), Different(Anders)***
	The use of modern techniques and the game itself were appreciated. There was never an elaborate explanation of why people thought it was fun, but overall the novelty and game were considered fun.
What did you like about the game?	**Keywords: *Reacting(Reageren), Immersion(Opgaan/geraken in de wereld)***
	The environmental and additional responses to the actions were received particularly positively.The therapists pointed out the

	particular addition of immersion as game feature that made it nice to play with.
What did you not like about the game?	**Keywords: *Start(Beginnen), Feedback(Feedback), Goal(Doel)***
	There was some disliked confusion about starting and following the exercises through. These were unclear, which made it slightly frustrating. A few people also pointed out that there was no clear goal to work towards, which they disliked.
Did you manage to perform the exercises correctly?	**Keywords: *I think so(Denk ik)***
	There was a lot of confusion by the asking of this question as it made people doubt if they really performed the exercises correctly. In most cases they did perform it correctly and were just confused by having been asked this question.
Was it clear what you had to do?	**Keywords: *Clarify start(Begin verduidelijken)***
	There was minor confusion with the start of particular exercises that didn't have obvious contextual handles, these could have been clarified.
Do you have anything else you want to say?	**Keywords: *Add Fine Motor Skills (Fijne motoriek toevoegen), Modern(Van deze tijd)***
	The novelty and the system's abilities were praised by several. Therapists expressed interest in possibilities with fine motor skills in further iterations of the game.
Only for therapists	
What do you think the system would be able to add for you?	**Keywords: *Focus attention(Aandacht focussen)***
	The real visible addition of this system seems to be its ability to cut off external stimuli and focus the patient's attention wholly on the tasks necessary.
What would you add to the system to make it more appropriate?	**Keywords: *Feedback(Feedback), More exercises(Meer oefeningen)***
	The suggestions to improve the system involve expansion of the practicable exercises both in variation and quantity, and improved performance feedback on the individual exercises, possibly by means of difficulty settings adjustment.

Discussion

The organisation of the experiments was quite chaotic due to limited time for preparation as the tests were quite hastily planned. This did not compromise the integrity of the individual tests with the various patients, but ensured that no proper recording was made of at least one of the patient tests, as was originally planned.

Additionally there were some complications with the setup that ensured that during this test the version of the product used was not the one described as the final one. Instead the version used was unable to process progression on picked up tasks. That meant that a task picked up from the corkboard attached itself to the controller, but never had tasks confirmed as having been performed. Hence it was decided that the players would not be asked to pick up a task from the corkboard, but instead were given tasks by the supervisor who also confirmed their having performed the task often enough.

There were few participants in the tests, but the information derived was very usable and indicative for the success of the research. Different information was derived from the two different parties and both gave the insight required of the different stakeholders.

Notable was that the participating patients and one of the therapists, who was nursing a neck injury, indicated feeling tired after the playtesting, but not to levels that were actually troubling. This was to be expected as feeling tired is common after wearing any virtual reality device. There was no need to stop a play session while the patient was performing exercises, but it did encourage earlier termination of the room to explore.

All things considered the tests were conducted in decent manner and performance was acceptable.

Conclusion

From the tests, the tested prototype can be concluded to fulfil the requirements of aiding player concentration on tasks and providing a fun experience alongside accommodating those rehabilitative tasks. While reception is tending towards positive there are indications of points for improvement in feedback and clarity.

Overall, the tests were a success and the meaning of the results will be discussed in the project conclusion.

Discussion

Ethical interests

Before addressing the project conclusion it is important to consider the ethical considerations that played part in the project. As previously mentioned stroke patients have suffered brain damage leaving them often with problems such as the inability to retain attention, speech and perception impairment and sudden headaches. Because of this stroke patients need to be regarded as a protected target group.

This has consequences for the different techniques that can be used in the game design elements. Whereas addictive mobile games have plenty of useful techniques for retaining attention, considerable care when consulting these methods should be taken. Furthermore, the amount of both mental and physical stress they are under can interfere with their recovery process. As this is not only adverse to the intended purpose of the design, but also morally wrong, this situation must be avoided at all costs. The design may not harm the patients or their recovery in any whichever way.

These aspects were regarded by not applying to nudging techniques to engage players, but instead only use methods that have been scientifically tested with the target group. The intermediate user tests were performed to ensure that the system would be safe for the final target group to test it. With these considerations it was decided that the interests of the patients have been considered and cared for.

Process

There were several minor hiccups in the process that required attention, but nothing that compromised the completion of the project within the allocated time. Hence the project was finalized according to planning with the discussed parameters and determined minimum requirements.

Due to unforeseen circumstances the product was finished later than originally planned. It was considered necessary to test the product with the target group or experts to determine the project's success. Due to time constraints the final user tests was therefore rushed. This had a negative effect on the amount of information collected from this test, though present information did suffice.

As for present state of use the information suffices the process was deemed suitable. For future continuation in any form it will be necessary to arrange larger scale tests with a better structure to accommodate collection of more information. Other than this the design, development and test processes were executed in a satisfactory fashion.

Conclusion

The tested iteration of the product meets the minimum requirements of the patients and therapists, but can be severely improved on several points. Nevertheless that means the project can be concluded as a success.

The minimal requirements for the patients were all fulfilled. The final iteration of the product contains, clear and short instructions in the form of given tasks explained with illustrative images. All implemented movements have a relation to meaningful actions as they have logical consequences and handles. There are 4 different exercises implemented for the player to perform. There is a reward system implemented for progressing through the exercises. Finally, the system can recognise and respond to the successful execution of a set exercises.

For the requirements from the therapists there were also implementation put in place. Buttons over the computer display allow the setting of tasks. The system is fully operable by someone without knowledge of the internal workings of the game. The in game actions of the player can be seen on the computer screen and the player can be seen moving in real space.

Additionally the system accommodates infinite repetition of exercises, supports the ability to influence the game from outside through the computer, and has rewards for every step of an exercise. There were no further implementations of any of the requirements mentioned in the MoSCoW Analysis.

The test results indicate a need to clarify the start of various exercise and better feedback on completion of the movement in later iterations. In further progression it would also be possible to add additional features that were requested during the final user tests and more of the research requirements that were described in the analysis.

In conclusion, a satisfactory product was produced in the allocated time and a clear idea was formed of how to improve the product in later iterations. The product was able to aid patients with concentrating on the tasks they were presented with in a minor way, but this requires more testing to get confirmation.

Future work

Future iterations of the product should focus on finalising the reward system by adding a task reward after completing a task. That should aid with overcoming confusion in completion of exercises. Implementation of a story and linear progression can also severely enhance the elimination of confusion by giving more purpose to the exercises.

It was suggested that the implementation of an artificial agent that could support a direct feedback loop to the player might be a worthwhile addition. Providing progression feedback in general is a good

addition for future development of the product with, for example, a printable report on performance during the play session for the therapists being formatted at the end of each play session.

The expansion of the list of programmed movements and their diversity is also definitely something to consider for future work on the project.

Afterword

With this, the project is finished. It has been a tremendous learning experience for me and a fantastic opportunity to work with the involved parties. I am incredibly grateful to be granted the opportunity to work in the field that I am studying for and be able to provide something that can be received positively. It has been hard work, but I have loved every step of the way.

Before closing off, I would very much like to thank a few of the people involved with the project, without whom it would not have gotten to the present state.

First, I would like to thank Joep Janssen for his accommodation of the research that was required for analysis and confirmation of the project. I have especially not made it easy with the final user tests and he has gone above and beyond to ensure that the project stayed on track and that sufficient information was available. Without your passion and enthusiasm this project would not have been possible. Thank you very much.

At Philips, I have been received the assistance of not one but a whole team of people who aided the project in some way. In particular, Cati Batterink Macarov has been a great support in the planning of the project, arranging meetings and accommodating work. All members and interns of the software concepts team were all wonderful to work with and helped in overcoming problems whenever they occurred. It has been a pleasure to work with all of you. Thank you for the wonderful time.

To Jean-Marc Huijskens, from Philips, I owe the entire project. The endless enthusiasm that you had for the project, the support for the work and the faith that you had were invaluable. From the initial idea onwards you have shown incredible interest without which it would not have been possible to go on this journey. Thank you for having faith and supporting every step along the way.

Finally, Robby van Delden, supervisor of this project, without whom it would have never gotten this far. The assistance in directing attention, focusing on the right aspects, arranging meetings and overall support have been more than anything I could ask for. Thank you for your availability and support.

7-7-2017

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Appendix A:

This appendix contains the notes from intermediate user tests.

All answers and questions will be in Dutch.

Vragen

1. Ervaring met Virtual Reality.

In VR

2. Wat vind je van de omgeving, hoe voel je je er in?
3. Hoe voel je je in VR?
4. Heb je de neiging op de tafels te leunen?

Uit VR

5. Ervaring actieve hand
6. Ervaring inactieve hand
7. Sturing start beweging reflectie
8. Sturing tijdens beweging reflectie
9. Beloning voltooiing reflectie
10. Overige

Uitleg

11. Vragen beantwoorden

Participants:

Participant 1: (geen ervaring)

- Erg voorzichtig
- Omgeving fijn
- Meer behoefte aan bevestiging

Participant 2: (geen ervaring)

- Moeilijk met links
- Heel doelgericht
- Behoefte aan meer sturing
- “heb ik het nu uitgespeeld”

Participant 3: (meerdere keren in VR)

- Kooi beklemmend
- Neiging dingen uit te voeren met hand zonder controller

- Sturing onduidelijk

Participant 4: (geen ervaring)

- Kooi veilig, Bergen bedreigend
- Wilde controller op tafel leggen
- Punt op controller lastig te bepalen
- Behoefte aan meer sturing
- Stelde veel vragen

Participant 5: (geen ervaring) → headset crashed

- Lengte een problem
- Collider problems
- Headset zwaar
- Moeite met besturing controller → gewaarwording

Participant 6: (geen ervaring met HTC Vive, wel met virtual reality)

- Gaat gewoon door tafel heen
- Merkt kooi, niet belemerend, mist deur
- Vermoeiend na 20 minuten

Participant 7: (lang geleden ervaring met headset)

- Stapt in objecten maar gaat niet door
- Kooi wordt gemerkt, maar is niet beklemmend
- Behoefte aan meer sturing → natuurlijke handvaten
- Geen poten, dus leunde niet
- Behoefte aan een doel

Participant 8: (korte ervaring Oculus bril)

- Manier van feedback op uitvoering oefeningen is cool
- Correlatie ruimte en omgeving onduidelijk
- Gebruik actieve hand kwam wel duidelijk
- Tafels zonder poten → niet leunen
- Beloning niet meteen duidelijk

Participant 9: (oculus beetje ervaring)

- Kooi voelde veilig voor echte wereld
- Actieve hand was duidelijk, geen neiging tot leunen of inactieve hand gebruiken
- Wel objecten mijden
- Vive op zich al cool
- Bewegingsinstructie duidelijk, gevolg mag duidelijker

Participant 10: (een keer eerder met de vive)

- “Waarom ben ik hier”
- Wilde controller neerleggen

- Feedback nodig
- Weidse uitzicht hielp
- Bevestiging dat dingen inderdaad bewogen

Participant 11: (klein beetje ervaring met 360 film kijken in bril)

- Omgeving was mooi
- Controller voelde als afstandsbediening.
- Actief bezig inactieve hand niet te gebruiken
- Had volledige instructie nodig voor bewegingen
- Beetje onwennig in VR

Participant 12: (walibi vr 1 keer)

- Poten maken dat je niet leunt, tafels maakt wel dat je dingen wilt oppakken.
- Kooi belemmert zicht
- Hoogte problemen
- Overzicht over beweging houden

Appendix B:

This appendix contains the quotes from the interview with participants of the final user tests that answered the specified questions.

All answers and questions will be in Dutch.

Vragen:

Vond je het leuk om op deze manier oefeningen uit te voeren?

Wat vond je fijn aan het spel?

Wat vond je minder fijn aan het spel?

Lukte het om de oefeningen goed uit te voeren?

Was het duidelijk wat je moest doen?

Heb je nog andere opmerkingen?

Voor de therapeuten alleen:

Wat denk de dat het systeem voor jou kan toevoegen?

Wat zou je aan het systeem toevoegen om het gepaster te maken?

Patiënten

Participant 1:

“Ja, is toch iets anders”

Interview was cut short after this question.

Participant 2:

“Ja, was wel grappig.”

“Het was leuk hoe je echt andere dingen kon doen en zo.” “Zoals de lichtjes uit de pot. De pot is het leukste.”

“Ik wist niet zo heel goed waar ik moest beginnen.”

“Denk het wel, toch?”

“Een beetje, was niet echt zeker.”

“Komt er nog een verhaal in, want dat zou wel leuk zijn.”

Participant 3:

“Ja, was leuk.”

“Dat alles reageerde op wat je doet. En het gooien met de flesjes. Ik kon echt veel.”

“Het was wel vermoeiend. En wist niet zo goed waar ik moest beginnen.”

“De plantjes waren was moeilijk, daar kon ik niet zo goed bij.”

“Ik had denk ik wel wat hulp nodig.”

“Het is wel mooi omdat het toch van deze tijd is.”

Therapeuten

Participant 1:

“Ja, is leuk.”

“Het sluit de stimuli goed buiten. Dat maakt het makkelijk om te focussen. Je raakt echt in die wereld.”

“Zou ik zo even niet weten. Ik zou misschien nog wat meer willen kunnen doen.”

“Ik had niet helemaal door wanneer je om moest keren, dus dat kan misschien nog wat beter.”

“Hoe zou dit beschikbaar zijn en gemaakt worden? Kan iedereen dit maken? Want het zou leuk zijn om verschillende dingen te hebben die beweging volgen zodat mensen kunnen kiezen.”

“Zeker met de belofte voor fijne motoriek zou dit heel interessant zijn. Dat de patiënten zich dan goed kunnen focussen op wat ze moeten doen.”

“Vooral meer oefeningen, ook verschillende soorten.”

Participant 2:

“Leuk om te doen.”

“Dan natuurlijk ook heel mooi dat, zoals ik had net de bril op en dat sloot alle impulsen af. Je was er wel, maar ik zag je niet. Dat opgaan in die wereld is heel goed op sommige punten.” “Bijzonder dat je samen in het spel kunt ontdekken.”

“Het is natuurlijk wel ook nodig om op te passen daarmee (met het opgaan in VR).” “Het is waarschijnlijk ook beter als je iets meer sturing kunt geven met specifieke opdrachten.”

“Ja, geen probleem, maar weet niet of voor iedereen de afmetingen wel goed zullen zijn.”

“Best wel.”

“Je kunt hier ook fijne motoriek mee doen, dat zou wel gaaf zijn.”

“Zou nu nog niet precies weten waar dit goed voor is, maar zeker als fijne motoriek er in zit is het nuttig om te kijken waar precies dit toegepast zou worden.”

“Nogmaals, fijne motoriek met dat ding (Touch pad) zoals je zei zou wel goed zijn.”

Participant 3:

“Mooi ding. Gaaf om dit te kunnen doen.”

“Het volgt je wel goed. En leuk al die dingetjes die aangeven dat er echt iets gebeurt. Dat is heel goed.”

“Ik mis nog een beetje een doel en een manier dat er feedback wordt gegeven over hoe de patiënt het doet en hoe ver die komt in bewegingen.”

- Vraag overgeslagen

“Mag misschien nog wel een betere uitleg in over waar te beginnen. Een soort van introductie over de acties.”

“Nee, was interessant.”

“Daar ben ik vooral nog heel benieuwd naar. Daar moet ik toch echt eerst nog een beter beeld van krijgen.”

“Feedback over hoe het gaat in de oefeningen, veel meer verschillende oefeningen, mogelijkheid om het zittend testen, misschien zelfs liggend en zittend.”