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AUGMENTED REALITY PHOBIA TREATMENT INCLUDING BIOFEEDBACK

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Abstract

People suffering from a persistent, irrational fear (phobias) try to avoid every possible confrontation with the phobic object. This anxiety has, as a result, a significant limitation of their life of those people. There are multiple treatment methods on the market to treat people with phobias. Two of the most common ones are In vivo exposure and virtual reality treatment. Both are proven to be very successful in treating phobic patients but still have some flaws which prevent the patient from an effective treatment. This paper outlines the possible implementation of augmented reality and biofeedback in current phobia treatment solving the detected problems of the earlier mentioned treatments. Two prototypes were developed, testing participant possible solution of an augmented reality treatment including biofeedback. The results from the prototypes show potential for further development and research in implementing a new way of treating people including the latest technology.

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Abbreviations

AR - **A**ugmented **R**eality

AT - **A**pplied **T**ension

CBT - **C**ognitive **B**ehavioral **T**reatment

CT - **C**ognitive **T**raining

EMDR - **E**ye **M**ovement **D**esensitization and **R**eprocessing

EXP - **Exp**osure Sessions

PMR - **P**rogressive **M**uscle **R**elaxation

SFQ - **S**pider **F**ear **Q**uestionnaire

SST - **S**ocial **S**kill **T**raining

VR - **V**irtual **R**eality

VRET - **V**irtual **R**eality **T**reatment

Chapter 1: Introduction

1.1 Current Situation

A person developing an irrational, persistent fear against an object or a public situation is called a phobia. The term phobia can be divided into three specific types. Special phobias are the fear produced by an object as arachnophobia (fear of spiders) or ophidiophobia (fear of snakes). An estimated percentage by the National Institute of Mental Health (NIMH) states that 8.7 percent of Americans in the US, which is equal to 19.2 million people suffer from one or several specific phobias (NIMH, 2017). A social phobia, on the other hand, is the fear of social interactions as ordering at a restaurant or answering the phone. The last type is called agoraphobia, which is the anxiety of being trapped in public situations. People having phobias often react terrified and try to avoid every possible case involving the confrontation with the feared stimuli. This persistent anxiety often forces this person to change their lives routines according to the anxiety and has a result of limiting their lives. In extreme cases, people develop such a high fear level which may lead to self-isolation with resulting depression.

There are several treatments available to treat phobias such as cognitive behavioral therapy, muscle relaxation, systematic desensitization or hypnotherapy. One of the reliable treatments is In vivo exposure. This treatment involves confronting the patient with the feared object in repeated sessions until the anxiety decreases to a certain level. Due to the massive amount of patients anxiety, this treatment is often refuse after hearing the procedure. Patients are too afraid of being confronted and therefore decide to continue living in anxiety as underlying the treatment. The technological approachment of phobia treatment is virtual reality treatment (VRET), which has proved to be a promising alternative to In vivo exposure. The patient, in this treatment, confronts the feared stimulus in a computer-generated three-dimensional environment. According to Garcia-Palacios, Botella, Hoffmann & Fabragat (2007) patients are more willing to accept this treatment than In vivo exposure because it provides a compelling alternative without being confronted directly with the feared stimulus. Downsides of this treatment are the missing feeling of presence during the treatment. Patients cannot immerse themselves in the treatment, and therefore the therapy seems unrealistic which suppose a critical disadvantage. This disadvantage contributes to the high

acceptance of patients undergoing this therapy but as a way to escape the confrontation with the anxiety.

1.2 Project

The approach of this project is using the disadvantages and advantages of both treatments mentioned above (In vivo exposure and VRET) and create a new innovative therapy including augmented reality and biofeedback. Augmented reality is a component of the overall term mixed reality which includes virtual reality and augmented reality. Compared to virtual reality in which the environment is fictional, augmented reality uses the real environment and project fictitious object, so-called “holograms,” on it. This technology may solve the missing feeling of reality experienced by the patient in VRET. Seeing the natural environment by the patients could be an essential characteristic that contributes to a higher reality sense of the patient. In addition to augmented reality, biofeedback will be a component of this project. The therapy will include heart rate data of the patient, which can be used by the expert. This data could contribute to a better performance of the patient and expert. Showing the heart rate provides valuable information about the current emotional state of the patient which could help the expert to correctly interpret the situation an adjust the session to the state of the patient. The right treatment of the patient is essential in phobia treatment because it can lower anxiety and facilitate a better quality of life for the patients. Besides, VRET is proven to be an effective treatment, and patients accept this treatment over In vivo exposure, improving this treatment by the implementation of augmented reality could provide a more effective treatment than VRET.

1.3 Research Questions

1.3.1 Main Research Question: Augmented Reality

How can augmented reality be implemented in the current treatment of phobias?

This research question deals with testing out the capacity of augmented reality. It is essential to know to what extent it is possible to use different functions of the Microsoft Hololens which can be used in the therapy. This question also deals with developing a promising alternative to In vivo exposure and VRET, solving the main problems of both treatments. As stated before both treatments present some problems when treating people with phobias, augmented reality could provide a suitable alternative solving most of these problems as the missing feeling of presence or reality.

Does the AR solve the central problem of VRET?

VRET is already proven to be an effective phobia treatment and a promising alternative to In vivo exposure. As mentioned before one of the problems of VRET is the missing feeling of presence which can assumably be solved with AR since it uses the real existing environment. It needs to be tested if this assumption which the project is built on is accurate and can provide an advantage over VRET and a better treatment to the patients.

1.3.2 Sub-questions

What characteristics determine people's perception of realism?

Patients complained about a missing feeling of presence while experiencing the virtual reality treatment, therefore has to be tested out what people perceive as real and fictitious. Realism has many characteristics as sound, movement, haptics that has to be ideally in harmony in an environment to perceive realism. Before answering the central research question, it is essential to determine how people perceive reality by using augmented reality. Knowing the characteristics of realism will give the possibility to develop different scenarios with a high reality level.

Following sub-questions can be asked:

Does the Implementation of haptics and sound improve the sense of reality?

Are the object projected on the actual environment real enough?

Can the participant emerge themselves in the setup?

1.3.2 Main research Question: Biofeedback

How can biofeedback be implemented that it is useful for the expert?

The second central research question deal with the implementation of biofeedback. Heart rate data could be a useful tool for the expert, during the therapy. The expert could use the data to get a closer insight into how the patient's current emotional state is and adjust the therapy accordingly to it. Patients being treated are set up to highly unusual stress, that if applied wrong, can produce a counterproductive effect and have damaging consequences for the patients as increasing the fear level.

1.3.3 Sub-questions

Does it affect the patient in any way seeing his heart rate?

The possibility appears that patients could get nervous by seeing their heart rate and feel uncomfortable during the treatment.

Following sub-questions can be asked:

Is the visualization through a heart object on the environment diminish the sense of reality?

Does this heart object distract the patients from the therapy?

1.4 Structure

The following report will start with chapter two the current state of the art describing different treatments used for treating people with phobias. The treatments are split up into traditional methods and technological methods which are explained in general with their advantages and disadvantages. The primary focus, however, will be on the already mentioned treatments above of In Vivo and VRET because of their positive treatment results compared to the others. Besides, also some information about the early usage of biofeedback in medicine and phobias is provided. In the next chapter, chapter three, the primary requirements of this project are discussed, with users, hardware and software descriptions, ending with the global requirements and the project concept. Chapter 4 and 5 describe the lo-fi and hi-fi prototype developed to answer the research questions mentions in the previous paragraph. The prototypes involve one treatment follow up with two different treatment setups which are used according to the participant. Chapter 7 based on the results from the previous prototypes, a project concept will be developed as a possible treatment with augmented reality. The report ends with a discussion for further research and a conclusion, summarizing the result from the prototype testing.

Chapter 2: State of the Art

2.1Traditional Methods

Cognitive-behavioral treatment (CBT) is one of the conventional therapies regarding anxiety disorder. According to Taylor (1996), CBT is mainly used to treat social phobias. Social phobias are fear of public social situation as presenting in front of an audience. This treatment, as explained by Taylor, usually includes four steps:

(1) Exposure session (EXP) involving homework assignments;
(2) Cognitive therapy which Choy, Fyer & Lipsitz (2006) state, means to restructure people distorted or irrational thoughts against their related anxiety with resulting decrease of it;
(3) Combined sessions of EXP and CT and
(4) Social skills training (SST) are methods of improving interpersonal skills such as maintaining a conversation or adequately eye contact.

Talking about the efficiency of CBT, Olatunji, Cisler & Deacon (2010), conducted analysis, stated that in comparison with medication treatment of social anxiety (social phobias)has a 100 % success rate in treating people seeking for help. Hazlett-Stevens & Craske (2002) described possible advantages and disadvantages regarding CBT. CBT turns out to be cost-effective compared to other treatments which could increase the number of people seeking treatment. Besides, people applying CBT can observe a rapid personal gain in a few sessions. Disadvantages of CBT are means regarding qualified therapists or adequate patients. The treatment often requires the therapist keeping the patient focused on task and goals while maintaining a strong therapeutic alliance. Not all therapists could be suitable for this treatment. On the other hand, not all patients are ideal for the treatment, since the patients need to be willing to participate and learn. Patients who are not interested are not suitable for this treatment.

Another way to treat phobias is systematic desensitization. This treatment based on Wolpes (1958) theory of “reciprocal inhibition “consists of reporting all the feelings by the imaginal confrontation of the feared object or situation of the patient. During the Imaginal

confrontation, the patients were taught to relax their voluntary muscles. According to Wolpe, the treatment is composed of three different components:

(1) Progressive muscle relaxation training (PMR);
(2) Construction of a fear hierarchy of the feared object and
(3) Desensitization.

The last component consists of the repetition of imaginal confrontation of the patient involving progressive muscle relaxation (PMR). McCroskey, Ralph & Barrick (1970) tested the treatment in speech anxiety which results in a significant decrease in anxiety after the procedure. Also, Agras (1967)claims that this treatment is not entirely suitable for treating phobic patients, since patients having a phobia “do not usually exposed themselves in every session” in other words, people do not often imagine their phobic situation during a session.

Similar to systematic desensitization is imaginal exposure. Imaginal exposure is the imagine confrontations of the patient with his phobic situation. This treatment often involves the doctor reading a case to the patient while the patient believes it. Unlike systematic desensitization by Wolpe (1958), imaginal exposure does not include the progressive muscle relaxation, Wolitzky-Taylor, Horowitz, Powers & Telch (2008). Rentz, Powers, Smits, Cougle & Telch (2003) study, compared In vivo exposure to imaginal exposure. Imaginal exposure showed a decrease of anxiety in the patient and proved to be an effective treatment. However, In vivo exposure had still higher effectiveness in treating people. This treatment compared to the In vivo treatment is thought to be more controllable of the patient’s reaction, and it is also easy to conduct for the therapist. Besides that, we encounter the same disadvantage as in the previous treatment.

Going away from the imaginal exposure or systematic desensitization, where the patient has to imagine the fear, eye movement desensitization and reprocessing (EMDR) confronts the patient via showing pictures of the phobic situation. EMDR is often used to treat post-traumatic events. Therefore the patient is exposed to photos showing the phobic target while the patient engages in a rapid eye movement, Wolitzky-Taylor et al. (2008). During the treatment, patients focus on a disturbing image, situation or memory, while the doctor moves a finger in front of the patient, which is tracked by him. Additionally, Jongh, Oord & Broeke (2002) divide EMDR into three parts:

(1) Facilitate the distress of one or multiple old memories;
(2) Decreasing the effect of anxiety;

(3) Preparation for a future confrontation with the phobic object.

According to Davidson & Parker (2001) meta-analysis of EMDR, where the efficiency was tested, both argue that EMDR showed improvement of the patient by reducing anxiety but also stated that the corresponding eye movement is somewhat unnecessary and not useful. Compared to exposure-based treatments, such as CBT or In vivo exposure, it is not an effective treatment. Also, Jongh (2002) found some disadvantages regarding EMDR. EMDR because of his additional component of different stimuli is only suitable for small, fast treatment sessions of ten minutes. In exposure literature, this is qualified as ineffective treatment. Also, as stated before, the additional eye movement shows no improvement and is therefore unnecessary.

Leaving all the treatment where people only confront the phobic situation by imagining it or pictures, some treatment includes as already mentioned in CBT actual exposure of the phobia to the patient. In interoceptive exposure, the patient in this treatment learns to deal with the anxiety by doing idiosyncratic exercises, Choy et al. (2007). These exercises mean the reproduction of internal physical sensations (choking, dizziness) and the patient is exposed to them in a controlled situation. According to Arntz (2002), interoceptive exposure is often used to treat a panic disorder such as claustrophobia (fear of small places). Arntz also argues that the treatment is as effective as Cognitive training (CT) which is a component of CBT. Therefore it is to conclude that this treatment is a successful treatment. Disadvantages, as Arntz explains, are the embarrassment of people while doing the exercises or the misbelief of successfulness of the procedure.

In vivo exposure is one of the effective treatments encountered in anxiety disorder treatment. Wolitzky-Taylor, Horowitz, Powers & Telch (2008) define In vivo exposure as a method of confrontation between the feared phobic object and the patient. Additionally, Lars-Göran Öst (1988) divides the exposer into four parts which are: Commitment, Confrontation, Further Approach, and Outcome. He explains that the patient has to commit to the exposure accepting the methods used without leaving the situation at any time. Furthermore, the patient has to approach as much as he or she can to the object until the fear decreases or disappear. After reducing the anxiety, the patient has to approach as much as possible to the object to reduce the anxiety level again. The session is concluded when 50% of the patient's anxiety level is reduced from the initial state. According to Bush (2007) In vivo exposure show many advantages and disadvantages. Of course, as Wolitzky-Taylor et al. (2008) already mentioned, In vivo exposure is one of the effective treatment that is currently

available. Besides, it shows a high success rate and is familiar to almost every therapist. Disadvantages, however, as Bush explained, Confidentiality of the treatment, limited therapist control, high treatment cost and unappealing to patients. In vivo exposure is not confidential because patients are confronted with their phobia, and it happens to be in public where patients could easily get embarrassed by showing their anxiety. Also, this therapy limits the control of the therapist since patients are directly confronted, and some reactions could be unexpected and unhandled by the therapist. Facing the real phobia also supposed a high treatment cost for the extra sessions is looking all different situation of phobias. Often these additional sessions are not covered by the medical insurance. Also, most of the patients refuse the treatment because of the fact facing her anxiety directly. Therefore it is unappealing to patients.

As mentioned before, several treatments implement other minor therapies such as applied tension & applied relaxation. These treatments will be briefly mentioned because of their small contribution to other therapies. Applied Tension (AT) is primarily used to treat people having a fear of blood or injections. In this treatment, the patients are exposed to stimuli regarding blood or injury and are instructed to tense their muscle to raise the blood pressure, thereby preventing fainting in the presence of blood or injections. Applied relaxation is similar to applied tension. The patient learns a specific skill to use when it is confronted with the phobic situation. In this case, the patient practices progressive muscle relaxation (PMR).

An entirely different approach is hypnotherapy. In this treatment, hypnotic techniques are used to induce the patient an altered state of consciousness or attention (“trance”), to overcome the anxiety. It is often used to cure patients suffering from dental phobias, Choy et al. (2007). Talking about the efficiency of this different treatment, Marks, Gelder & Edwards (1968) compared hypnotherapy with systematic desensitization (mentioned before) and found out that systematic desensitization was more effective than hypnotherapy, one reason for that was that the hypnotic state did not last so long. Another disadvantage was the availability of the treatment. Not every medical institution has such a therapist. Summarizing the main problems of each treatment we can conclude following disadvantages in traditional methods:

- Cost-effectiveness appealing to patients
- Safety and privacy
- The therapist is not suitable for treatment
- Availability of treatments
- Limited control of the therapist

- Time-consuming

2.2 Technological Methods

Due to the technical development in the world, also treatments regarding phobia applied some technology to it. One of them is virtual reality treatment. Most of the authors agree on the general definition of virtual reality treatment. The first two authors agreeing on their definition are Rothbaum, Hodges, Smith, Lee & Price (2000).) and Krijn, Emmelkamp, Olassov & Biemond (2004). Both define VRET as shown in figure (1) as a treatment that emerges the patient in a 3D computer-generated environment facing his phobic object. Additionally, Emmelkamp, Krijn, Hulsbosch, de Vries, Schuemie & van der Mast (2002) state that virtual reality integrates several sensors, computer graphics, and body tracking devices, focusing more on the technical part of virtual reality. Besides, Rothbaum points out the "sense of presence," which the patient gets during the treatment allowing them to process emotional the treatment to his stimulus of fear. Also, Krijn, Parsons & Rizzo (2007) argue, that VRET works well with the emotion-processing model. This model states that through the confrontation with the feared or threatening stimuli, the fear network of the patient needs to be activated in a way that new information can be added to the emotional status. Several studies were conducted, were in vivo exposure was tested against virtual reality treatment; surprisingly this treatment is as efficient as in vivo exposure including several advantages. Bush (2007) as mentioned before stated several disadvantages regarding in vivo, this disadvantages can be seen as advantages of virtual reality treatment, such as cost-effective, privacy and safety and time-consuming. This innovative treatment is according to Garcia Palacios, Botella, Hoffmann & Fabregat(2007) is more welcomed by the patients over in vivo exposure. Virtual reality also displays some advantages of In vivo exposure regarding cost active, less time consuming, privacy and safety. The disadvantage of VRET is the missing feeling of presence and motion sickness. Also, the problem is that people choose virtual reality treatment over In vivo exposure to escape from the real confrontation. These patients often cannot attach emotionally to the procedure. The cave is the technological alternative to virtual reality treatment allowing the patient to confront the phobic object by guiding a virtual person, through the computer, to interactions with the phobic situation.

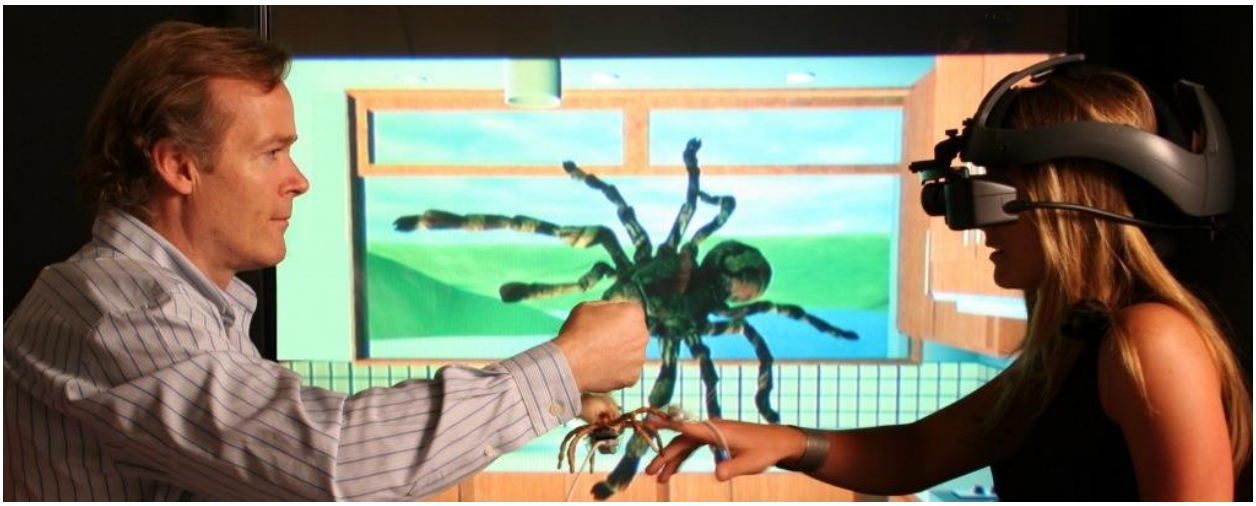

Figure 1: Virtual reality treatment of arachnophobia (fear of spiders)

However, there is already something regarding augmented reality in phobia treatment with spider and cockroaches. The patient faces the insect in a real environment with a projected insect on it for example on the table, as shown in Figure 2. The program recognizes where to put the animals via a patch. The patient while being exposed can add animals or delete them according to the anxiety level he currently has. According to Juan, Botella, Alcañiz, Carrion, Melero & Lozano (2004) the AR treatment showed significant efficacy in treating phobia of spiders and insects in general.

Figure 2: Augmented Reality Treatment of Katsaridaphobia (fear of Cockroaches)

According to this project, it will differ since the Microsoft HoloLens provide multiple functions as the function of spatial mapping which makes a mesh from the room and identifies the

objects where they can be placed on (no need of a patch). Also, no biofeedback is integrated yet in this treatment.

2.3 Biofeedback

The implementation of biofeedback could become a potential tool for the expert while treating the patients. Biofeedback could help the expert to understand better the patient's body and feelings and can react accordingly and provide the patient with the best therapy possible. However, Rice, Blanchard & Purcell (1993) conducted a study about treating general anxiety disorder (phobias) with biofeedback. A small group of participants was split up into a group with only cognitive behavioral therapy and therapy including biofeedback. As a result of this study, the slight decrement of patients anxiety was archived with patients having biofeedback. The study did not show a significant outcome of biofeedback being helpful. Rice, as one of the reasons, stated that to get substantial insight if biofeedback is useful, a more critical test group is required. Also stressing out that people undergoing treatment always show a decrease in anxiety and therefore do not believe in biofeedback as being helpful. On the other hand, Wenck, D'Amato & Leu (1996) tested approximately 150 children who were classified as anxious by the teacher to anxiety reduction. The children were divided into a biofeedback group and nonexperimental group. The outcome of the experiment after sessions with muscle relaxation and accompanied EMG biofeedback reduce the anxiety of the children significantly. Therefore it using biofeedback in phobia treatment can be useful for both the therapist and the patient.

Chapter 3: Requirements

The following chapter describes the concept analysis and context of the project. Since the project is about creating a new treatment for phobic patients, the next step is to analyze the background, meaning having a detailed description of the users which will be using the treatment afterward. For this purpose personas and scenarios were created to give a better insight of which user type can be expected and the typical reaction towards the feared object. Further on the chapter the available software and hardware will be described and presented. In the end, the global requirement will be provided.

3.1 Context Analysis

For understanding better the context of this project and deepen the understanding of the treatment methods and underlying psychology, current phobia treatments were researched on the previous section of this report laying out their benefits as well as deficits. State of the art brought a broad knowledge in theory which only could be implemented by experts in the field of phobia treatment. The goal of those interviews was to broaden knowledge of phobias, their background, treatment method and the current use of virtual reality in phobia treatment. Additional objectives were to acquire information on psychopathology and its latest developments, providing useful literature references that are used in psychopathological education. Finding formal patients, who have (had) a phobia, can help in the design process of the project. Two companies were asked to participate, and both agree on sharing their knowledge to contribute to this project. Unfortunately, none of them replied on the following emails, and therefore no expert interviews could give a broader view of this subject. The selection procedure for both meetings was a convenience sampling, where the respondents were approached individually with a request to participate in the project which would provide a huge help for this project.

3.2 Analysis of Users

The analysis of the user contributes to getting a better understanding of which kind of people this project requires. The users of this therapy will be arachnophobia (fear of spiders) patients and therapist. These patients suffer from an extreme fear of spiders and try to avoid

every possible confrontation, which constrains their lives immensely. When confronted with their fear patients often react with (NHS, 2018):

- Dizziness
- Sweating
- Trembling
- Panic
- Pain or tightness in their chest
- Shock stated
- Rapid heartbeat

Although of their vast fear, patients using this therapy should be open to testing new technologies and willing to overcome their fear. Experts, on the other hand, should have the technical knowledge to handle the installation/system (hardware & software) correctly and be willing and open to testing new therapy methods. The expert should also have expertise in treating phobia patients and the capacity to interpret the patient's current emotional state to apply different levels of this therapy. For both users and therapists, we have made personas based on our findings of above sections. The characteristics of the potential users of our system are described in these, and we expect to design our system with these in mind. What will follow are a few scenarios involving these personas, the personas themselves can be found in the appendix.

Due to the failed requirement of an expert in this project and the short amount of time to get the medical approval of this project, the user evaluation and test will be tested with users having a slight fear of spider or none fear of spiders. The risk of damaging people because missing expertise is too high and not acceptable for this project.

3.3 Personas

According to the analysis of the users explained in the previous chapter, personas had been developed to get a better understanding of how users could be in future treatment. The presented personas are fictional and only created for this project and should only provide some characteristics and behaviors encountered through the research, but every single patient differs from each other, and therefore this is not guaranteed description of stereotype personas. Every description of the personas contains a personality table to get an overview of aspects of their lives which is affected by the phobia.

3.3.1 Thomas Smit (Suffers from Arachnophobia)

Figure 3: Thomas Smit (fictitious)

Age: 34

Status: Single, employed

Every time Thomas sees a spider, he flinches. He tells himself it's not that bad, while actually, he is really anxious. He breathes in and out a few times, trying not to run away, and tries to carry on. During work, he easily gets distracted by images of cute puppies. His co-workers like an occasional spider related prank and Thomas just laughs along, though deep down, he hates them with all his heart while he's off to the bathroom to recover. He still lives in his mother's basement.

Personality table	Low	Medium	High
Level of fear		x	
Willing to face fear/learn to cope	x		
Affects lifestyle		x	
Acknowledges fear is ungrounded		x	
Avoiding behavior		x	

Table 1: Personality table Thomas Smit

3.3.2 Lea Buscher (Suffers from Arachnophobia)

Figure 4: Lea Buscher (fictitious)

Age: 58

Status: Married, employed

Lea's fear of spiders is so extreme; it gruesomely affects her daily life. She's always on the lookout for spiders. She thinks she might encounter spiders in every corner of every house, and under every table or chair. This causes her to live in fear. She cannot explain precisely why she is afraid of spiders that much, but she has nightmares of them crawling around all over her bed. She managed to get a job in the hospital because she believes that hospitals should be clean and because she believes she is safer there, working is currently her only way of escaping her fear. She is very eager to search for help concerning her phobia since she is tired of living in fear.

Personality table	Low	Medium	High
Level of fear			x
Willing to face fear/learn to cope			x
Affects living style			x
Acknowledges fear is ungrounded		x	
Avoiding behavior			x

Table 2: Personality table Lea Busche

3.3.3 Luis Rafecas (Suffers from Arachnophobia)

Figure 5: Luis Rafecas (Fictitious)

Age: 17

Status: Has a caring 'girlfriend' at school, goes to school

Luis is a young boy. He goes to school, but other kids make fun of him because of his fear. This makes Luis sad. He doesn't want to be made fun of. The only problem is that he screams like a little girl, every time he (thinks he) sees a spider or feels he is walking through a web. To make matters worse, his parents don't support him, and he thinks ill of himself for his weakness. At the end of each day, he cries himself to sleep. He also uses a vacuum to clean his room every morning and makes sure not to have any dust or spiders or webs. He has nightmares about having spiders crawling from between his sandwiches. Most nights, he wakes up screaming. He is too scared to face his fear

Personality table	Low	Medium	High
Level of fear			x
Willing to face fear/learn to cope	x		
Affects living style		x	
Acknowledges fear is ungrounded			x
Avoiding behavior			x

Table 3:Personality table Luis Rafecas

3.3.4 Silvia Lang (Treater of Arachnophobia)

Figure 6: Silvia Lang (Fictitious)

Age: 32
Status: Lives with partner, employed
Computer knowledge: Limited

Silvia has not worked with VR applications to treat arachnophobia before. She is an excellent therapist, but her knowledge of computers is limited. Things like Microsoft Word she can work with very well, but she has no experience in working with 3D applications.

3.3.5 Leon Elk (Treater of Arachnophobia)

Figure 7: Leon Elk (Fictitious)

Age: 43
Status: Single, employed
Computer knowledge: Good

Leon is experienced in working with VR applications for the treatment of arachnophobia. His knowledge of computers is good, which allows him to use the tools in the current treatment to a reasonable extent.

3.4 Scenarios

3.4.1 Thomas's story (arachnophobia patient)

At first, Thomas rejected to undergo treatment for his phobia, because he is too afraid of being confronted with a spider. As a child, Thomas had a traumatic event involving one of his family members being bitten by a spider and dying short time afterward on a trip to Australia. After years of living in anxiousness, he decided to seek treatment. The therapist, because of the traumatic event, started slowly with AR treatment. The goal is to decrease his panic when confronted with spiders.

3.4.2 Lea’s story (arachnophobia patient)

Lea has been actively searching for ways to treat her phobia of spiders. She thinks the AR treatment will help her cope with her daily struggle. The treatment could start out with a simple spider that is sitting on a table or nearby surface and could be expanded upon by making the spider walk. This will help to get away from the horrid feeling associated with the crawling of spiders so that she might have fewer nightmares of spiders crawling everywhere.

3.4.3 Luis’s story (arachnophobia patient)

Luis’s sweetheart wanted to help him, so she and her mother made an appointment with a doctor to see if his phobia could be treated using augmented reality. Luis was very scared to go since this would involve facing his fear.

The treatment Luis gets starts out with cognitive behavioral therapy, to sort things out in his mind about the fear. In a later stage, the AR treatment would come into play. Luis knows his fear is not grounded in facts or logic, but he still panics at the sight of a spider. The AR treatment will start out ‘easy,’ a (not so realistic) spider will be projected on a table. Luis and his treater can gradually increase the level of his treatment, slowly building towards less panic and fear on the sight of a spider.

3.4.4 Silvia's story (arachnophobia therapist)

Silvia is new in the field of phobia treatment with AR, so she will need to learn how to get around in the workspace. She will need written instructions nearby to check what specific actions she can do with the HoloLens. With her skills as a therapist and the implemented biofeedback, she will be good at deciding when to take the next step in treatment, and what that step will be.

3.4.5 Leon's story (arachnophobia therapist)

Leon has worked with VR applications in his treatments before, making it a familiar environment for him. He is able to use the options the VR platform provides to full extent. This gives him a lot of possibilities regarding editing the way spiders will look in the virtual reality, to the way a VR spider moves and feels. Now he has heard about the new treatment with augmented reality. After a few thoughts, he will add this technology as current first treatment.

3.5 Software

3.5.1 Unity

This software developed by Unity Technologies in 2005 is a cross-platform game engine which is used to create three-dimensional games and two-dimensional games. Unity supports drag and drops options for users to develop their own game and C# scripting. Besides that, it supports more than 27 platforms to build in games such as PlayStation, Xbox, and Oculus Rift. This software is also able to connect to the HoloLens of Microsoft which will be explained in the next section. In addition to the software, Microsoft and unity create especially for the HoloLens the "Mixed Reality Toolkit," which provides for every interested developer of Unity and augmented reality the possibility to easy drag and drop examples and standard scripts. The software is freely available on GitHub. Unity also provides with an asset store multiple opportunities to implement objects in the setup when developing the lo- and hi-fi prototype for the user evaluation in this project.

3.6 Hardware

3.6.1 Microsoft HoloLens[1]

Figure 8: Microsoft HoloLens

Microsoft HoloLens (See Figure 8) is a pair of mixed reality smart glasses developed by Microsoft. Under mixed reality, different terms can be derived from, which are virtual reality and augmented reality. The HoloLens contains a significant computing power which makes it able to walk freely in a room without connecting to an external device. Besides that, it includes also build in sensors, high definition lenses, and speakers. With the high definition lenses, it makes possible to see the real environment and project holograms on it. Also, the HoloLens has multiple functions which can be useful for this project. The most important features will be discussed briefly:

3.6.1.1 Gaze Function[2]

The gaze function enables the HoloLens to track users focus. Via a little dot on the view field, the Hololens always can determine what the user is currently focusing through his head position. The gaze function could provide a fascinating insight into how phobia patients directly focused when entering a treatment setup.

3.6.1.2 Gesture Function[3]

[1] https://www.microsoft.com/de-de/hololens/hardware
[2] https://docs.microsoft.com/en-us/windows/mixed-reality/gaze
[3] https://docs.microsoft.com/en-us/windows/mixed-reality/gestures

The HoloLens provide an option of moving an object through the environment with specific gestures. This function could be used to include the patient in the treatment interactively and provide an active treatment. Also, it might raise the perception of reality of participants compared to VRET. A gesture which could be useful and at the same time real could be the “Air tap” seen in figure 9. With a simple hand gesture, the patient could grab holograms and move them around.

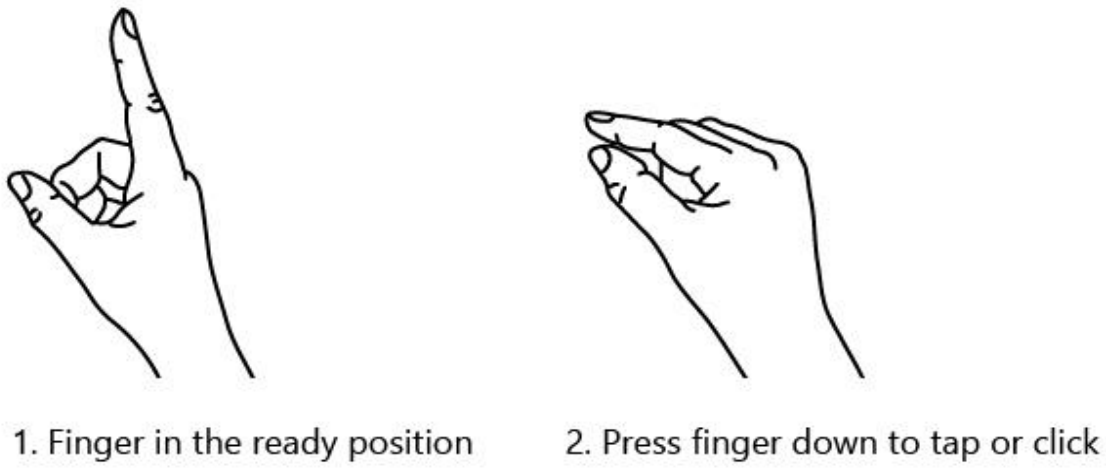

Figure 9: Air Tap Function of HoloLens

3.6.1.3 Spatial Sound[4]

The sound engine from the HoloLens makes it possible to implement sound according to distance, directions, and environment. The patient entering the setup could determine via this function where the holographic object is located in the environment. This function as the gesture function could contribute to the perception of reality experienced by the patient since the sound from objects or animals are also determined by the direction and distance.

3.6.1.4 Spatial Mapping[5]

Spatial Mapping allows the developer to analyze the room for the augmented reality experience. The HoloLens determines whether the room has surfaces where holograms can be placed on and look as natural as possible. Therefore a mesh of the room is created (Figure 10) which can be afterward used to create a setup with realistic interacting objects on it.

[4] https://docs.microsoft.com/en-us/windows/mixed-reality/spatial-sound
[5] https://docs.microsoft.com/en-us/windows/mixed-reality/spatial-mapping

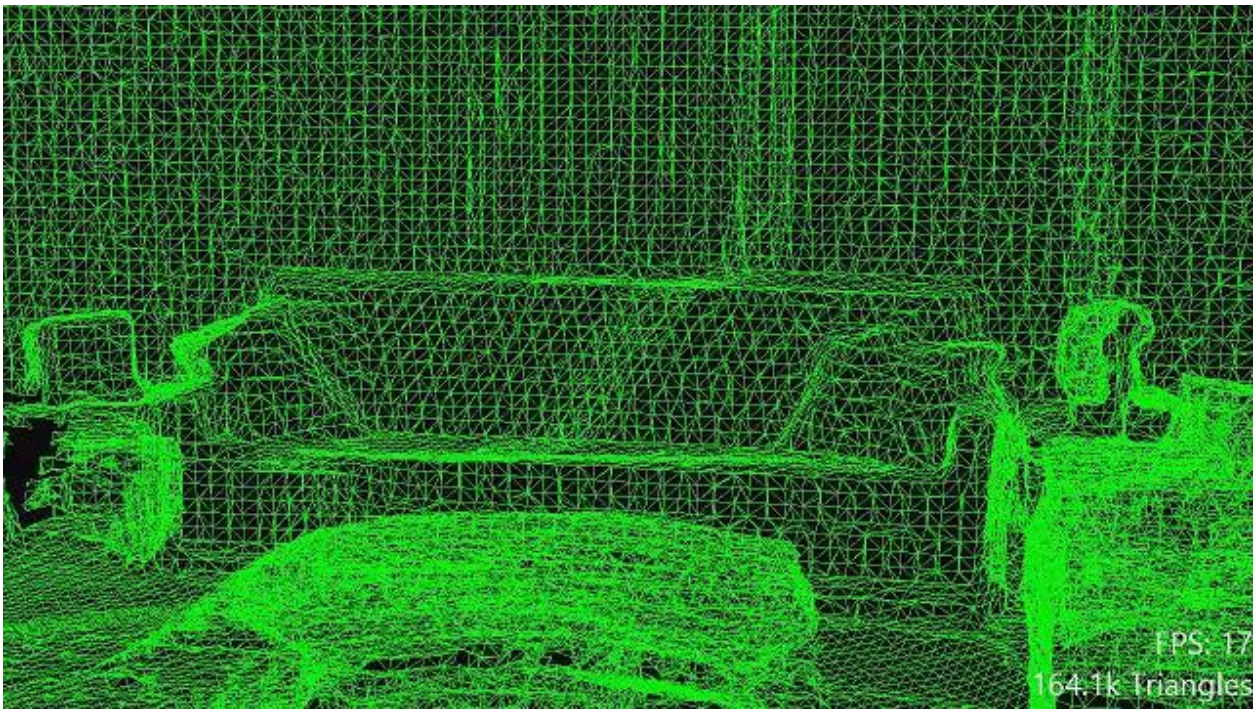

Figure 10: Example of a room with a covering mesh

3.6.2 Moto 360 Smartwatch

Figure 11: Motorola Smartwatch 360

The Smartwatch[6] (See Figure 11) produced by Motorola will also be one of the leading gadgets in this project. The Moto 360 has a built-in activity tracker which can measure the heart rate activity of the users. The data will be used for the implementation of biofeedback in the treatment. The smartwatch presents a convenient and comfortable solution to gather heart rate activity. The patient will not be wired up with cables which could limit the moving interaction within the treatment.

3.7 Global Requirements

There are some requirements that the therapy should conform to, divided between functional, usability and user requirements. The technical elements include the primary functions of the Microsoft HoloLens, as being able to walk freely in the room and use the features to interact with the holograms. Usability requirements describe how well the device performs when in usage; in this case, it should be easy for the patient and expert to use. Lastly, the user requirements describe all how both user and expert should be able to use the installation, for instance, a patient might want to quickly leave the simulation if the perceived stimuli are too powerful, or a treater might realize this himself already and do it for the patient.

ID	Type	Requirement
RQ1	Functional	The device should display realistically the holograms fitting to the real environment.
RQ2	Functional	The device should enable the patient to interact with the holograms.
RQ3	Functional	The device should enable the patient to walk freely in the room
RQ4	Usability	The device should be easy to use from both the treater and the patient's perspective

[6] https://www.motorola.com.au/products/moto-360

RQ5	Usability	The controls on the device should be intuitive and do not need an extensive explanation
RQ6	User-expert	The expert should be entirely in control over the treatment by being able to change how the simulated spider is presented to the user
RQ7	User-treater	The biofeedback should be visible for expert during the treatment
RQ8	User-patient	The patient should be able to quit the simulation quickly in case he or she panic
RQ9	User-patient	The patient should feel like he or she is in control of the simulation
RQ10	User-patient	The patient should know that there is no actual danger
RQ11	User-patient	The patient should want to learn to cope with the fear

Table 4: Global Requirements

Chapter 4: Lo-fi prototype

4.1 Design and evaluation of lo-fi prototype

4.1.1 Introduction

This project is aimed at developing a new treatment for people with phobias using augmented reality and biofeedback. With this new treatment, disadvantages of virtual reality and in vivo exposure could be solved and provide a unique alternative to people seeking for help.

In this chapter, the development of one lo-fi prototype was discussed. The user testing using the lo-fi prototypes is described, covering participant recruitment, user tasks, evaluation, and methodology. The results that the lo-fi prototypes have yielded are discussed and based upon this, and the requirements have been modified.

The primary goal of this user evaluation was to find out people's perception of reality displaying the real environment with projected holograms. Besides, the functionality was tested for problems which may disturb the impression of realism and the influence of the evaluation.

Do participants experience reality in the prototype?

For implementing a certain reality level, it is necessary to know what characteristics contribute to people's perception of reality. Therefore it is essential to ask the participants how real the spider feels and what could be further implemented, to increase the reality level.

How is the functionality of the installation?

The perception of participants realism also depends on the interaction of the installation with the participant. Realism can often be interrupted if interaction with the installation has problems or glitches appear that have an impact on the smoothness. Therefore it needs to be tested if participants discovered some of these mentioned problems on the installation.

How can biofeedback be implemented to be useful?

Biofeedback can be a useful tool for the expert but can be a disadvantage for the participant if it disturbs focusing on the central challenge of the therapy or has an adverse effect on the patient itself. It is essential to investigate how biofeedback can be implemented and how it can be useful for both expert and patient.

4.2 Evaluation design

A low fidelity setup including principal objects has been prepared to answer the research question of what characteristics determine participants perception of realism.

4.2.2 Prototype set up

The prototype was tested on the University of Twente Campus in the HMI Lab located in the Zilverling building. The HMI lab was split up in two part, one evaluation part, and a questionnaire part (Figure 12 & 13). Participants were allowed to test without any obstacles and liberty, the augmented experience, whether participants waiting or already done with the evaluation could sit down and fill in the questionnaires. This room splitting was designed to prevent participant waiting their turn.

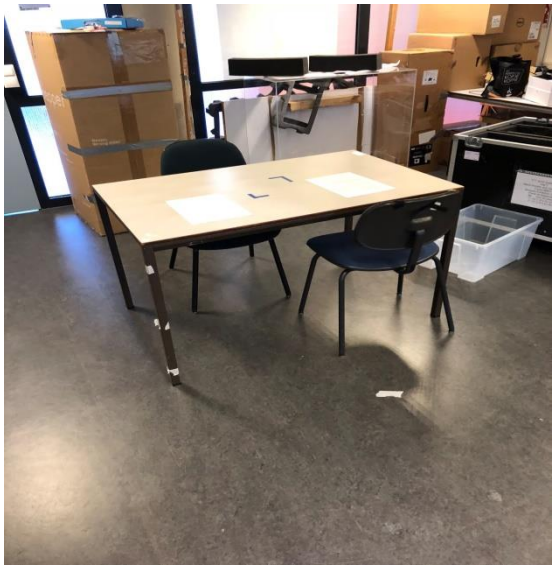

Figure 12: Questionnaire-Part

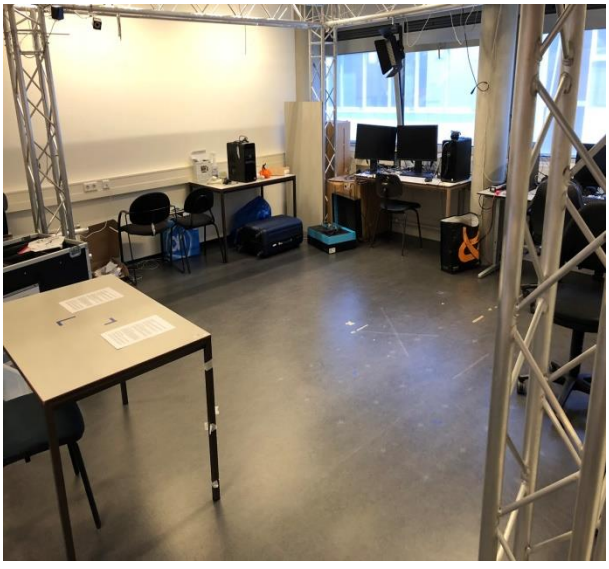

Figure 13: Evaluation-Part

4.2.3 Prototype

The prototype consisted of a heart placed on the wall and a spider[7] and box[8] on the floor (See Figure 14 & 15). The objects were placed well away from the participants to prevent uncontrollable reactions if a patient turned out to be afraid. Participants were asked to analyze the spider and box and the whole environment including the heart. After the participant analyses the objects and the environment, the challenge was given to move the box and spider from the starting position. As a final challenge even to put the spider in the box. This simple set up was made to find out how real the environment was to the participant, and if functionality problems appear during the evaluation. The Hi-fi prototype will probably include all three objects encountered in this prototype evaluation. The reason for placing the spider at a reasonable distance has several purposes. Firstly, because of safety issues, even if people score a low level of fear in the Spider Fear Questionnaire, the situation could happen that people react fearfully to the projected spider. Secondly, placing the spider away from the participant diminished the possibility of participants instantaneously spotting the spider and recognizing it as a not real one.

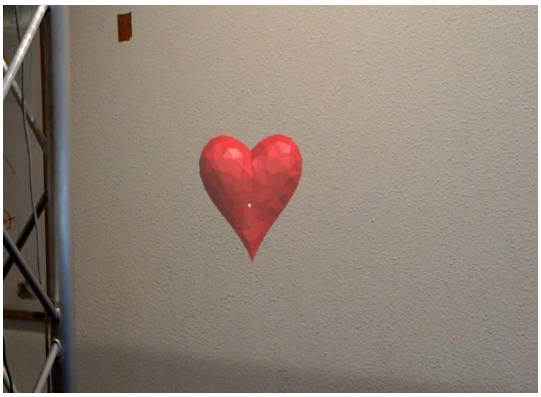

Figure 14: Heart-hologram placed on the wall: Heart-hologram placed on the wall

Figure 15: Carton box and spider placed on the ground

[7] https://assetstore.unity.com/packages/3d/characters/animals/animated-spider-22986
[8] https://assetstore.unity.com/packages/3d/props/cardboard-boxes-pack-30695

Figure 16: First fake spider

4.2.4 Goal

The goal of this test was to find out how comfortable a user would be with approaching and getting close to a realistic model of a spider, similar to how those would be simulated later in the hi-fi prototype. Besides of that, if any object displaying the heart rate would take the attention of participants to the actual challenge. Lastly, the functionality was also investigated because it could be involved in participants perception of realism. Answering this question will give valuable information that can be used to design the final hi-fi prototype of this project.
Notably, the primary goals to investigate are:

(1) How real the participants evaluate the environment with the objects?
(2) How real does the spider look to the participant?
(3) Does the system have any functionality problems?
(4) Does the implementation of biofeedback distract the participant from the actual challenge?

4.2.5 Participants

Participants were recruited via a convenience sample. A nonpublic invitation was sent on WhatsApp groups and public request via the confrontation with possible participants. Participants who agree on participating in the lo-fi treatment prototype evaluation where asked to do a questionnaire to determine the level of fear and

exclude them if they score a certain level of fear to provide security of the participant and disclosed unnecessary disconformity in participants. The Spider fear Questionnaire (SFQ) has a score from 0 - 31, every participant is excluded from the evaluation phase if they scored a number higher than 10 (Appendix 5). The average number of phobic patients is 23,2, and the group archived an average score of 4 (sd: 3.6). Every participant scoring between 0.0- 10.0 will be accessible for the evaluation.

4.2.6 Demographics

Eight participants, six male, and two female met the requirements to participate in the lo-fi prototype. Every participant finished the evaluation successfully. All participants belonged to the University of Twente except one participant. The average age of the evaluation group was 23 years. (Range= (19,28); sd: 3.1)

4.2.7 Procedure

Before starting the procedure, participants were asked to fill in the SFQ to determine if the participant was able to participate under the condition stated before. Before starting with the evaluation, the informed consent and information brochure was given to every participant to read through. Participants were also given the possibility to ask questions if any doubt or confusion appeared. After resolving every question, participants were kindly asked to sign both documents to proceed with the evaluation. The evaluation started with the researcher, giving the instructions (Appendix), explaining the environment and actions the participant is capable of doing with the Microsoft HoloLens. It was stressed out again that the study is about spiders and participants would be exposed to a spider during this evaluation. Besides that, it was also strongly advised that participants could stop the evaluation at any given time without any consequences and this would also provide valuable feedback for the research.

Starting with the evaluation, the participants should as a first step analyze the environment. Participants could walk freely through the evaluation part of the HMI lab analyzing the objects concerning reality. During the evaluation, the researched asked continuously question regarding the topic mentioned before. As a second part of the evaluation, the participants were told to move the objects and placed them in different positions as before. Afterward, a short interview was held where participants had to answer another questionnaire.

4.3 Prototype Evaluation

4.3.1 Observation & Results

The lo-fi prototype was evaluated using a semi-structured interview. After each iteration, a series of questions were asked consisting of 14 open questions and 16 closed questions. Some of the questions were inspired on the presences questionnaires developed by Regenbrecht & Schubert (no published year) and Witmer & Singer (1994). The questionnaire can be found in Appendix D.

4.3.1.1 Realism

The reactions of the lo-fi prototype were roughly the same for most participants. Most participants found the spider exciting and not fearful, and even some participants characterized the spider as “cartoonish” and “funny.” The spider scored an average score of 5.29 (sd: 1.03) on the reality level, which already approves the previous mention reactions of the participants. When asking participants about their feelings towards the spider, 86 percent had a neutral feeling and did not felt any fear. However, two participants feel uncomfortable seeing the spider and hesitate to approach or felt disgusted by the spider, but after a while, all counties felt off, and participants iterate with the spider as being the cartoon box without any discrepancy. The cartoon box, on the other hand, looked more natural and fitting to the environment as the spider, because of their realistic material on the object.

Asking the participants if adding sound and haptics would improve the general perception of reality, 86 percent positive agreed on these two elements as a crucial factor to determine if the environment feels real or fictitious. In addition to the implementation of sound and haptics, participants also advise in adding more movement to the setup. The reality was diminished because the spider animation was only showing an “attack” movement on one spot without the spider moving around.

Besides asking participants how the reality level of the objects was, some presence questions were asked to get an insight of how participant perceive themselves being in the setup with holograms. Every participant had the impression that the objects were three dimensional and not two dimensional giving a less real impression of the setup. A 100 percent also agreed on the objects as being separate from the usual environment meaning that the objects were clear to distinguish from the real world

and therefore a very negative result in solving the central problem of virtual reality treatment.

4.3.1.2 Interaction

Most of the participants could interact well with the holograms. Only a few inexperienced participants had difficulties with "grabbing" the holograms. Overall the system got excellent feedback about the interaction. None of the participants experienced motion sickness or any glitches in the program which contributed to a proper evaluation session for every participant. Almost every participant, on the contrary, complained about the limited view of the HoloLens. This disadvantages is due to the HoloLens and can hardly be corrected by the researcher until new devices appear on the market.

4.3.1.3 Biofeedback

A heart hologram was displayed to give people a slight idea of how biofeedback would be implemented in the treatment. 70 percent agree that displaying this heart hologram would increase the nervosity level of the patient having a counterproductive effect of decreasing the fear level when treating people. All participants agreed on the improvement of the treatment if the expert is able to see the heart-rate. Although different opinions appeared in the question if the hologram would drag the attention against the actual challenge, participants were unclear whether it would be a distraction during the treatment.

4.3.2 Conclusion

4.3.2.1 Realism

The fact that all participants approached the holographic spider without hesitations indicates that that spider did not archive the reality desired and therefore it needs to be replaced. Some missing characteristics of realism such as movement and sound lead to the following result of the spider being unreal. Interestingly and unknown before was the fact that the material could also contribute to realism as the cartoon box did with his original sprite. Overall we can conclude that the spider diminished the perception of reality and therefore it needs to be replaced by another more realistic spider. Besides, participants also advise of the possibility to increase realism by

introducing multiple moving spider objects. Following problems should be replaced in the hi-fi prototype:

- Look of the spider was too basic and looked digital
- Missing movement
- Missing shadows

All these reasons contribute to spider as being unreal and therefore a significant improvement goal for the next prototype. Besides that, the cartoon box fitted well in the environment and most participants proved the box to be almost real.

Another aspect for improvement in the hi-fi prototype is the feeling of presences. Every participant agreed on the objects being separate from the real environment, with the effect that the participants did not perceive the setup as being real. Therefore new setups have to be developed in the hi-fi prototype to increase the perception of participants. Possible solutions could improve the setup by changing the mentioned above spider hologram with sound and movement or changing the setup to a more realistic situation in real life.

4.3.2.2 Interaction

The conclusion which can be derived from the interaction test is very definite. The interaction had an overall good impression by the participants, no glitches or motion sickness appeared with a resulting proper test evaluation for each participant. Only small changes in the “grabbing” function have to be made.

4.3.2.3 Biofeedback

Lastly, the biofeedback left mixed feeling towards implementing it visually on the treatment or just for the expert. The reaction towards this question has a mixed resonance from the participant which makes it hard to take a satisfactory conclusion from it and therefore it is a topic for further research. Since most of the participants agreed on only the heart-rate being visible for the expert, it will be hidden from the participants in the next hi-fi prototype.

4.3.2.4 Overall Conclusion

Overall it can be concluded that archiving visual realism of participants has many characteristics to keep in mind. Therefore the primary goal of the next prototype testing is to replace the spider. Also, it has to be considered, that the prototype testing took place using people that were not diagnosed with arachnophobia, and thus, their reaction might be very different from actual patients. The way in which people that have arachnophobia react to spiders will be assumably different from the responses that were acquired using non-arachnophobia patients. Regarding the functionality of the system, only a few adjustments will be made which such as feedback for grabbing object since this was the chief complaint of the participants. Biofeedback, however, has to be tested again for regarding position and functionality as displaying the actual data retrieved from the watch.

4.4 Revised Global Requirements

The lo-fi prototype gave a first insight of how such a treatment should be developed. Therefore the global requirements had to change accordingly based on the results from the test.

ID	Type	Requirement
RQ1	Functional	The device should display realistically the holograms fitting to the real environment.
RQ2	Functional	The device should enable the patient to interact with the holograms.
RQ3	Functional	The device should enable the patient to walk freely in the room
RQ4	Functional	The device should be able to display realistic movement of the spiders
RQ4	Functional	The device should be able to receive simulated sound from the virtual object based on the position
RQ5	Usability	The device should be easy to use from both the treater and the patient's perspective

RQ6	Usability	The controls on the device should be intuitive and do not need an extensive explanation
RQ7	User-expert	The biofeedback should be visible only for expert during the treatment
RQ7	User-expert	The expert should be entirely in control over the treatment by being able to change how the simulated spider is presented to the user
RQ8	User-patient	The patient should be able to control the spider moves by using the gestures accurately
RQ9	User-patient	The patient should be able to quit the simulation quickly in case I panic
RQ10	User - patient	The patient should feel like he or she is in control of the simulation
RQ12	User-patient	The patient should know that there is no actual danger
RQ13	User-patient	The patient should want to learn to cope with the fear

Table 5: Revised Global Requirements I

Chapter 5: Hi-fi prototype

5.1 Design and evaluation of lo-fi Prototype(s)

5.1.1 Introduction

After discussing the results of the lo-fi prototype were the participants rated the realism, interaction, and usage of biofeedback in the lo-fi prototype. The following chapter deals with the user testing of the hi-fi prototypes, covering most of the parts of the lo-fi prototype chapter. Different than in section four, the recruitment of participants and set up remain the same, besides some changes.

The primary goal of this user evaluation is to compare the developed scenarios including augmented reality with the existing virtual reality treatment. Following questions will be answered in this chapter.

Do participants experience a higher reality level than in the lo-fi prototype?

The perception of realism in the lo-fi prototype was negative according to the participants. As mentioned before, the participants rated the overall realism-level with a low score stating the main problem, in the spider hologram. The spider hologram instead of provoking a scary or anxiety feeling in the participant provoked the opposite and was defined as “cute, cartoon spider.” The spider hologram was replaced with another more realistic, tarantula-like spider[9] which can be seen in figure17. Besides the implementation of a new spider hologram, participants in the lo-fi prototype were positive about implementing sound and haptics to raise the realism-level in the treatment. Therefore a “scary crawling sound”[10] was introduced in this hi-fi prototype.

[9] https://assetstore.unity.com/packages/3d/characters/animals/giant-spiders-animated-57111

[10] https://www.pond5.com/sound-effect/49408627/creepy-crawly-critters-crawling-2.html

Figure 17: Tarantula Model used for hi-fi prototype

Do the presented scenarios with augmented reality solve the central problem of virtual reality?

As mentioned before in chapter two, the main problem of virtual reality is the missing feeling of reality. Phobic patients describe VRET as a non-realistic treatment because they missed the feeling of being present in the treatment. With both developed scenarios in augmented reality treatment, it is necessary if participants have an overall higher perception of realism compared to virtual reality. To have the best comparison possible, the setups were created leaning on actual In vivo exposure treatment methods from a BBC series called “My Extreme Animal Phobia” which can be found on YouTube. These series shows how people are treated with a fear of special phobias and including also a patient having an extreme fear of spiders.

Is the implementation of biofeedback useful in phobia treatment?

The lo-fi prototype yielded a positive resonance about defining biofeedback as a useful tool for the expert. Participants rated the implementation from fictional scenarios which would be included in the treatment. Therefore in this user evaluation, biofeedback will be tested regarding usability and functionality. This testing will provide a closer insight of how valuable the gathered data is for the expert and if according to this, the expert can adjust scenarios, treatment methods and get an in-depth look of participant current emotional state.

Do participants confront their phobic object or situation alone or accompanied with an expert?

From state of the art, it is known that phobic patients are often embarrassed because of their irrational fear. Therefore patients often refuse treatment because of being humiliated in public when confronting their phobic situation as in In vivo exposure. This might also be the case when the patient faces their fear jointly with an expert. This question will answer if participants prefer to enter treatment with a shared environment where the expert and patient can interact together in the augmented scenario. Alternatively, instead, prefer being observed by the expert through an external device and confronting the fear object alone.

5.2 Evaluation design

5.2.1 Prototype setup

For each participant, both treatments were tested in the same room directly one after the other at the University of Twente campus in the HMI Lab. The room as explained in the lo-fi prototype is split up into two parts, one questionnaire part and on the testing part as seen in the pictures. The Recruitment remained the same as in the lo-fi prototype with non-public invitations through WhatsApp groups and public requests via the confrontation with the participants.

5.2.2 Prototypes

5.2.2.1 Scenario 1: Floor full of spiders (Figure 17)

This scenario was a shared experience where participants could interact in the same environment. The environment consisted of a number of spiders crawling on the floor of the HMI- lab. Besides, both participants could hear a crawling sound of the spider walking on the ground. The participants were split up into “expert” and “patient.” The experts got the task to analyze the current state of the patient by observing the heart rate when interfering with the scenario. The participant was asked to investigate the functionality of the scenario and the realism-level encountered.

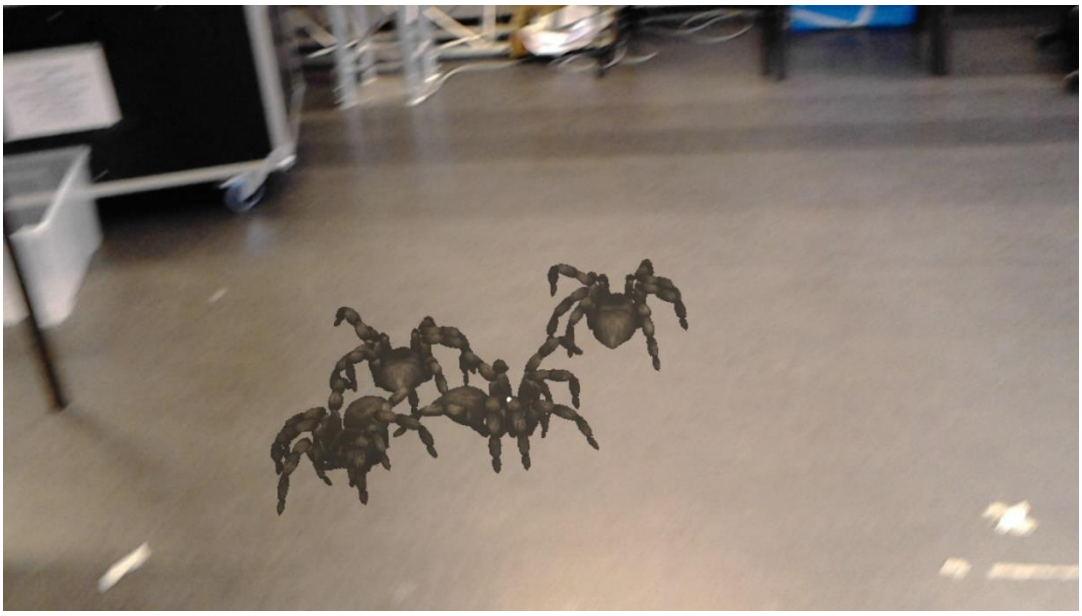

Figure 18: Floor full of spider setup

5.2.2.2 Scenario 2: Spiders and Boxes (Figure 18)

Different than in the first scenario the expert was following the patient experience via an external device such as a mobile phone or pc. Therefore the patient experiences the scenario alone. The scenario similar to the lo-fi prototype consisted of three boxes and three spiders distributed through the testing area of the HMI-lab. The patient was asked to search for the spiders and put them into the three boxes. The expert got the same task as in scenario one, which was observing the patient's heart rate.

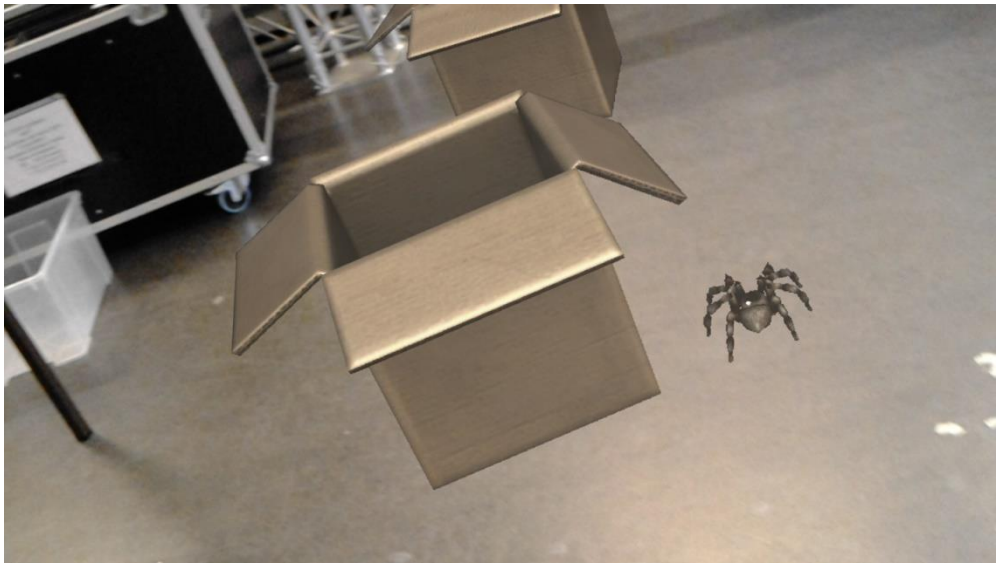

Figure 19: Spiders and Boxes setup

5.2.3 Goal

Both scenarios were developed to give the participants a closer insight into how augmented reality treatment could be in the future regarding phobia treatment. The primary goal is to provide suitable scenarios which can be compared to virtual reality treatment and get a closer insight if participants perception of realism is higher than in VRET. Therefore both scenarios will be tested concerning reality, which includes questions about presences and realism of the objects.

Besides reality, biofeedback is tested regarding usability. Participants acting as an expert will get the possibility to get an experience of how an expert would perceive the patient according to the heart rate and emotional state. The goals can be summarized into:

(1) Get a closer insight into how patients feel through biofeedback?
(2) How patients perceived realism compared to VRET?
(3) Does the system contain any problems regarding functionality?
(4) Do participants prefer a shared environment?

5.2.4 Recruitment and Demographics

The recruitment of the participant followed the same procedure as in the lo-fi prototype. After completing the SFQ with an average of 3 (sd: 0.71), 20 participants (eleven males and nine females) could be recruited for the hi-fi prototype. Every participant finished the test successfully without any complaints. The average age of the participants was 22 years (Range:17,31; sd: 3.15).

5.2.5 Procedure

Before starting the procedure, every participant received an information brochure and informed consent and was asked to read it through and ask questions if something was unclear.

After understanding everything and signing both documents, participants were told to finish the SFQ to determine if the participant is usable for this evaluation. If the participant gets a low scale of the SFQ showing no fear or a small amount of fear of spider the evolution can

continue with testing both treatments. Before testing both treatments, the user gets the instructions (see Appendix C) from the expert to make sure that during the test phase, the participant knows how to act in every situation and how to handle the challenges given from the expert. Again before starting with the evaluation it was stressed out to the participants that, they can stop the evaluation at any time and without a rapprochement and that will also provide valuable information. In addition, it will also be mentioned again that the test results will remain private and only used for this project and no other purposes. Starting then the evaluation phase, participants received virtual reality glasses and a video showing virtual reality treatment of arachnophobia (See Figure 19 & 20). This video dealt with a purpose to compare both treatments in means of realism, which was asked in the questionnaires after the test phase.

Figure 20: Virtual Reality Glasses

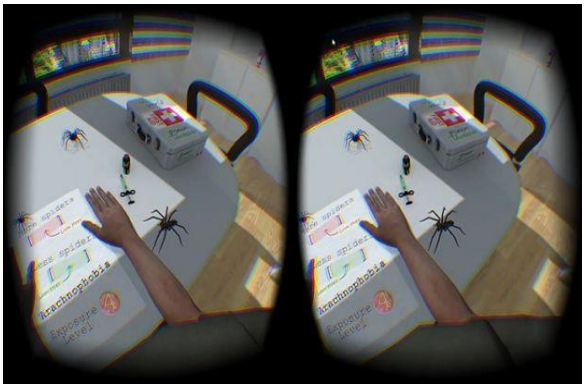

Figure 21: Virtual Reality Arachnophobia treatment

5.2.5.1 Scenario 1: Floor with Spiders

In the first scenario, participants and the experts position themselves in the room a few meters away, facing each other. After that, both put on the Microsoft HoloLens and start the application situated in the HoloLens menu. The participant sees the expert in front of him. Both can now analyze the environment with the spiders crawling on the floor. The participant playing like an expert receives a mobile phone connected to the smartwatch, worn by the participant performing the patient, and observed the heart rate from the patient. The patient on the other sides is asked to analyze the system carefully in terms of glitches or any other problems and how the objects are perceived compared to the real environment. After the evaluation, both received different questionnaires (Appendix E & F) about their findings in the first evaluation part.

5.2.5.2 Scenario 2: Spiders and Boxes

After filling out the questionnaires, both participants changed roles. The expert gets the smartwatch from the patient, and the patient, on the contrary, receives the smartphone from the expert. Reversing the roles gives the possibility for the participants to experience both scenarios playing both roles and provide valuable information with different views. The second scenario starts with the expert distributing the spiders and carton boxes all over the room. After finishing distributed the mentioned before holograms, participants were told to put on the HoloLens. Before starting the real test, participants were able to run a test of functionality regarding the gaze function of the HoloLens to clear out confusions and misunderstanding of the interaction. As a next step, participants received the challenge of searching for the spiders in the room, approaching them and putting them into the carton box. While the participant is interacting with the second scenario, the expert is following the experience via an external device. The expert will be able to follow the experience in live streaming observing what the patient is doing from his view. Afterward, both received the questionnaire which is to be filled out from the other point of view as in the previous filling.

5.3 Prototype Evaluation

5.3.1 Observation & Results

5.3.1.1 Realism

After implementing the new spider which looked close to a tarantula, the general impression from the participants changed according to the lo-fi prototype. 60 percent of the participants classified the spider as being realistic. Also, the first required neutral feeling gathered from the lo-fi prototype while watching the other spider changed in this prototype. The new spider acquired some disgust or anxious reactions on participants that were not afraid of spiders. These reactions already improve by far the reality level encountered in the lo-fi prototype. Also comparing both spiders, the tarantula scored an 8.85 over ten on the scale and showed a significant advantage against the previous spider with only a score of 5.29. The new spider indeed increments the reality level and perception of participants compared to the lo-fi prototype. Even 65 percent agreed on phobia patients perceive this new spider as being real and suitable for treatment.

5.3.1.2 Comparison with VRET

The participants watched a video showing virtual reality treatment in real life wearing virtual reality glasses with a phone inside displaying the setup. Afterward, they got the chance to try the setups created in augmented reality and compare both concerning realism and presence. 95 percent agreed on AR being more realistic than virtual reality treatment and furthermore solving the central problem of VRET. This result can be seen as a very positive outcome in terms of improving the actual technological treatment of VRET. Also, most of the participants perceive the objects as being real and well placed on the actual environment which also reinforces the improvement against the lo-fi prototype and the actual virtual reality treatment.

5.3.1.3 Experience

When asking participants if a shared environment would be preferable for treating arachnophobia patients, 65 percent agreed on that with the explanation of supporting the patient while treatment instead of facing the feared alone. Also interacting both in the same environment the expert could get a closer insight of how patients confront the fear and could change task instantly to trigger different reaction or improve the treatment.

5.3.1.4 Biofeedback

To prove the usefulness of biofeedback in the treatment of phobia patients. Participants were split up into two groups where one group did have the biofeedback implemented in the setups and the other a fictitious scenario how it could be implemented. The result of both groups was surprisingly the same when determining the usefulness. 95 percent of the group with biofeedback proves that having the heart-rate from the patient could improve the treatment in terms of getting a closer insight of how patients feel some situations or how the current emotional state is. Therefore the expert could adjust the treatment during the treatment and slowly treat the patient. The group without biofeedback surprisingly agreed on the same term and statements that the group with biofeedback. Also, 95 percent of the participants agreed on biofeedback as being helpful for the expert.

5.3.1.5 Functionality

Every participant could test without any problems both hi-fi prototypes. Some participants stated that the spiders in the setup ”Floor full with spiders” sometimes stayed in one position which could signify a glitch or error in the code but did not have a significant impact on the

participants. Also, the grabbing function of the HoloLens was for most participants, not a problem. The overall functionality remains satisfying as in the previous lo-fi prototype.

5.3.2. Conclusion

After stating the results, the research questions could be answered. The hi-fi prototype provided useful information that can be used to gather a closer insight into how a proper therapy would be with augmented reality and biofeedback. Answering the questions stated before for this hi-fi prototype we can conclude that:

(1) Participants did experience a higher reality level than in the lo-fi prototype

With the newly introduced spider model with crawling sound and actual real movement, the perception of reality did increase than before in the lo-fi prototype. Therefore the characteristics of reality discovered in the previous test proved to be accurate and contribute to an overall higher reality level of the installation. The most critical reactions of participants, having a slight fear when entering the setup for the first time and classifying the spider as disgusting and fearful, prove the level of reality.

(2) The presented scenarios indeed solve the central problem of virtual reality treatment

The implementation of augmented reality did resolve the primary issue of VRET. Participants declared as the main factor while comparing both treatments that the usage of the real environment already contributes to a higher perception of realism. The introduced holograms with the movement and sound fit well in the environment with an effect of an entirely credible setup for treatment according to the participants. Overall it can be concluded that the use of augmented reality solve the central problem of VRET since the patient has it more accessible to emerge himself in the treatment by looking at the real environment and his real hands. Of course, the primary factor while developing such treatment with AR is the implementation of the right objects with their characteristics to archive a realistic effect.

(3) The implementation of biofeedback is indeed a useful tool for the expert

Biofeedback could be a powerful tool for the expert while treating people with phobias. Every participant agreed on their implementation to gather a closer insight into the patient's current emotional state, and according to this adjust the treatment session not to stress out the patient. An expert could act accordingly to the patient's state and therefore provide a better and for every patient's individual treatment to treat their anxiety.

(4) When developing a treatment with AR, it should be in a shared environment

A shared environment can help the patient to overcome more easily their anxiety when they act in a shared environment with the expert. Therefore the expert can provide mental and physical support to the patient when being in therapy. This like all the other points mentioned in this conclusion has to be tested with real patients having a fear of arachnophobia to make proper assumptions.

5.4 Revised Global Requirements

After the test results from the hi-fi prototype, a final version of the Global requirements can be composed.

ID	Type	Requirement
RQ1	Functional	The device should display realistically the holograms fitting to the real environment.
RQ2	Functional	The device should enable the patient to interact with the holograms.
RQ3	Functional	The device should enable the patient to walk freely in the room
RQ4	Functional	The device should be able to display realistic movement of the spiders
RQ5	Functional	The device should be able to receive simulated sound from the virtual object based on the position

RQ6	Usability	The device should be easy to use from both the treater and the patient's perspective
RQ7	Usability	The controls on the device should be intuitive and do not need an extensive explanation
RQ8	User- expert	The biofeedback should be visible only for expert during the treatment
RQ9	User- expert	The expert should be entirely in control over the treatment by being able to change how the simulated spider is presented to the user
RQ10	User- patient	The patient should be able to control the spider moves by using the gestures accurately
RQ11	User- patient	The patient should be able to quit the simulation quickly in case I panic
RQ12	User - patient	The patient should feel like he or she is in control of the simulation
RQ13	User- patient	The patient should know that there is no actual danger
RQ14	User- patient	The patient should want to learn to cope with the fear
RQ15	User-patient-expert	The treatment should be in a shared environment

Table 6: Revised Global Requirements II

Chapter 6: Treatment Concept

Based on the results of the prototypes a possible concept including augmented reality and biofeedback is developed in this chapter. The concept is just an idea of how treatment could be in the future. There will be probably a vast space for further development and changes when developing a treatment to treat real patients since the result of the prototypes are with participants with no or just a little fear of spiders. Of course, this concept will be only for treatment of phobias including insects or small animals. The dimensions which this technology can reach will be the subject of further research.

The treatment should start with the usual process of a phobia therapy which include the patient doing the Behavioral Avoidance Test (BAT). This test determines the fear level of every patient can be modified to different kind of phobias. As already done in the lo-fi and hi-fi prototypes the patients should answer either the Spider Fear Questionnaire (SFQ) or the Fear of Spider Questionnaire (FSQ) which is also used in many scientific types of research. After determining the fear level of the patient an explicit instruction of what will happen in the treatment should be given to disclosing possible mistreatment of the patient. Once this is done the patient can proceed to the actual treatment. The patient and the expert will put on the augmented reality glasses and interact in a shared environment together. With the shared environment, the expert can have an impression of how the patient behaves during the treatment and applied different tasks according to the fear currently encountered of the patient. Besides, the shared environment is used to support the patient during the treatment and to give confidence that the patient can fulfill and beat the fear.

The treatment itself should be leveled in such a way that the patient can experience different levels of anxiety. The term leveled means that the treatment should be initialized with one first setup for every patient and according to the fulfillment or failure of tasks then proceed to the next level. The initial setup, for example with arachnophobia, could be the expert and patient standing in front of each other a few meters away. The expert is standing behind his desk. The patient would see the expert behind his desk with a holographic carton box. When the patient feels ready, the expert could place the carton box somewhere on the ground, and under it, a spider would appear crawling on the table. The following task could be similar to the procedure as in In vivo treatment, which is giving the patient the task to approach the animal as close as possible, in this case, the holographic spider. For this task, the patient

can take as much time as he requires. When the patient manages to arrive at the desk with the holographic spider crawling around, the next task the patient could ask would be to hold the spider in his hands. According to the fulfillment or failure of this task then the patient would proceed to the next levels which could be similar to the setups developed in the hi-fi prototype. When the patient manages to hold the spider on their hands, then he could proceed to the "spider and boxes“ setup, and the next task would include being the patient active and grab the spiders and put them into the boxes. Adding more spiders to it would increase the fear level instead of only having one spider in the setup. Otherwise, if the patient fails to hold the spider on the hands, he would proceed to the Floor Full with Spiders setup and only the number of spider would be increased, but the task would remain the same by walking towards the expert and again giving him the task to hold the spider. Once he manages to fulfill the final task, he could then proceed to the setup “Spiders and Boxes.” The setups and treatment levels are always leaning on the current therapies of In vivo and VRET.

Biofeedback would have a primary role in this treatment. The patient would have a smartwatch on his wrist sending his heart rate to the expert. The heart-rate would only be visible on the view field of the expert, such as presented in Figure 22, where the expert could see the heart and heart rate of the patient during the treatment. Otherwise based on the results the heart-rate could have a counterproductive effect by raising the nervosity of the patient or uncomfortable feeling. The expert, on the other hand, can use the heart rate to adjust different setups or tasks according to the current emotional state of the patient. This implementation could prevent the patient from being set up under an unusual amount of stress with resulting increasement of anxiety or mental damages.

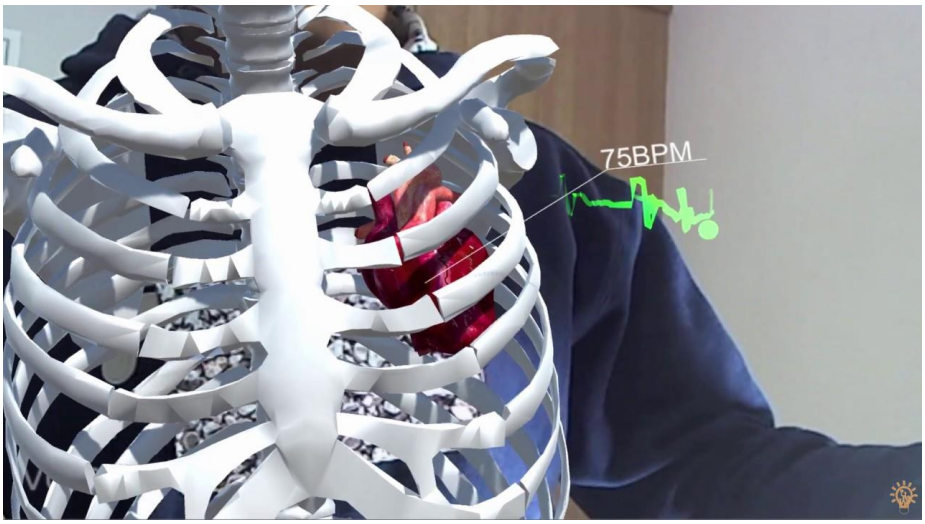

Figure 22: Example of implementing the heart rate of patients and vision of expert

Chapter 7: Conclusion

The goal of this project was to design a compelling approach for an augmented reality phobia treatment including biofeedback. By looking at the existing relevant treatments on the market and researching relevant literature a good insight could be gained about phobias are currently being treated and what steps a treatment should have. Based on the results of the hi-fi prototype, were the developed setups and holograms raised the perception of reality on participants even provoking some disgust and anxiousness reactions, can be seen as a successful implementation of augmented reality in phobia treatment. Participants wholeheartedly agreed on this method being an advantage over the previous technological therapy including virtual reality which reinforced the previous result of the reality level. Biofeedback added in the way as in the hi-fi prototype seems to have a positive impact on the participants when analyzing the other participant and to adjust the current treatment. The hi-fi prototype showed significant results when answering the research questions stated in the introduction and therefore it can be concluded that:

(1) How can augmented reality be implemented in the current treatment of phobias

This Question was answered in the previous chapter, describing based on the finding from the prototypes how an AR treatment should be. Summarizing the results of the test we can determine some characteristics the therapy should have:

- Realistic Holograms
- Moving Holograms
- Spatial Sound
- Shared environment
- Active participation of the patient

The setups should lean to actual treatment setups of In vivo exposure or VRET since the methods used from both therapies are proven to be effective. Of course as mentioned in the previous chapter, this finding, and developed model is just an example of how AR could be integrated. There needs to be further research with actual patients having arachnophobia or other phobias. In addition, it has to be mentioned that the model described in chapter 7 is only for treatment of little animals or insect and different phobias required different treatment methods.

(2) Does AR solve the central problem of VRET?

The Hi-fi prototype did provide a clear response to this question. Participants agreed on AR solving the main problem of VRET which is the missing feeling of presence. The usage of the actual real environment with a realistic object causes a high perception of realism in the participants. Already including the real environment facilitate participants to emerge themselves in the treatment because they do not experience any delay in the transmission of the stream such as in virtual reality or see an environment, body which is fictitious. Implementing AR solve already the central problem of VRET, the real challenge to create an environment entirely realistic for the patients are the implementation of the holograms. The holograms should be very detailed and have almost realistic movement, behavior, and sound. Without these characteristics, the patients could also have problems in emerging themselves in the therapy and have the same problem as VRET.

(3) How can biofeedback be implemented that is useful for the expert?

As explained in the previous chapter and based on the findings of the prototypes, biofeedback should be included only visible for the expert. That could be via a little icon on the view field of the expert showing the heart-rate data or on via a live stream on the computer. The gathered data could significantly help the expert to evaluate more precisely the patients and according to the emotional state, adjust the treatment session or challenges during the therapy. However, this is again only based on the findings from the prototypes and has to be tested with real patients. The participants in the prototypes agreed on being visible their heart rate would feel them uncomfortable, but it might be the case that it helps the patient to calm down when seeing the heart-rate from themselves or even of the expert.

Overall Conclusion

Summarizing everything, it can be concluded that this project solves at least some problems encountered in other treatments and has the potential to be a suitable alternative to other treatments regarding phobias. Even if the prototypes were tested with participants not having a fear of spiders some interesting and useful information could be gathered and give a closer insight on which characteristics such treatment should have. Of course for an ultimate verdict about AR being a potential treatment in the future, the treatment should be tested with real patients.

Chapter 8: Further Research

Including augmented reality and biofeedback in phobia treatment could provide a new innovative treatment method for future phobic patients. This project is just a small piece of research on how the latest technology could be implemented, and there is just a lot of space for further investigation before entering the market as a new therapy. The most important factor when speaking about AR as VR is the reality level provide in the setups. Therefore a setup with a low level of reality turns out to be ineffective for patients since they cannot emerge themselves in the situation. The project tested a few possible characteristics to raise the perception of reality such as realistic holograms of the objects, movement of holograms and sound feedback, but there is room for improvement and new characteristics that can be implemented. As already asked in the lo-fi prototype, the implementation of haptics, in other words, touch simulation would increase even more the perception of reality. There is already some clothes being developed that can simulate touch via there special materials.

Besides raising the perception of reality, the whole variability of the possible treatment should be further research. Virtual reality and In vivo exposure provide considerable variability when treating different kind of phobias. Augmented reality, therefore, should be tested how many phobias can be treated. An assumption can be made that this treatment should cover almost every possible special phobia type (every phobia including an object) since every object could be recreated with a hologram.

As for the biofeedback part, there is still to need to be proven if the patient sees their heart rate would feel uncomfortable. It might be the case that the results presented in the prototypes of this project are casualties of the participants and biofeedback would have a “calm down” effect on patients. Then several implementation techniques could be further research. As an alternative idea and not familiar in phobia treatment could be the implementation of a game therapy. Patients have to overcome the setup by having a low heart rate.

As the last point for further research is the effectiveness of the treatment. The project was tested with participants having no fear of arachnophobia. The results, therefore, should be verified with real patients to have a closer insight f how to improve the treatment and to test the overall effectiveness. A possible method to check this would be to have a large number of phobic patients and splitting them up into three groups. One group would be with virtual reality treatment, the second with in vivo exposure and the last group with augmented reality.

After a few treatment sessions, the anxiety level of the patients should be compared and look at the percentage of decreasement of fear in every patient in the three groups.

Appendix

Appendix A - Informed consent form

I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the information brochure laying before me. My questions have been answered to my satisfaction.

[ ] I agree of my own free will to participate in this research.

[ ] I am aware that I have the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time.

[ ] I hereby give permission to use my research results in scientific publications and scientific presentations. My personal data will not be disclosed to third parties without my express permission.

If I request further information about the research, now or in the future, I may contact David Bel Lang on either his email; d.s.bellang@student.utwente.nl or his phone; +4915236229393. As an alternative contact, I am also free to contact his supervisors Khiet Truong and Michel Jansen or their emails: k.p.troung@utwente.nl or m.jansen-1@utwente.nl. If I have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, Drs. J.M. Strootmann, P.O. Box 217, 7500 AE Enschede (NL), telephone: +31 534 896 719; email:ethics-comm-ewi@utwente.nl.

Signed in duplicate:

…… ……
Name subject Signature

I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.

…… ……
Name researcher Signature

Appendix B - Information brochures

Information brochure: Study augmented reality phobia treatment with biofeedback

Dear Participant,

Thank you for your interest in taking part in this final bachelor project regarding augmented phobia treatment of arachnophobia (fear of spiders) with biofeedback. This is an information brochure providing you detailed information about the general outline of this project and especially of this user evaluation.

Please read carefully through the information brochure and take your time. If you have any questions related to this user evaluation or in general about the project, don't hesitate to ask questions. You can find my contact (David Bel Lang) on the last page of this brochure.

What is the goal of the project?

The goal of this project is to create a new innovative therapy including augmented reality and phobia treatment. It is known that previous treatment like in vivo exposure (direct confrontation with the feared object) and Virtual reality treatment (confrontation with the feared object in a 3D recreated world) have several disadvantages. This known disadvantages often lead patients in avoiding therapy.

With this user evaluation, I try to solve the disadvantages of virtual reality and the missing feeling of reality by implementing augmented reality. Besides, that biofeedback will be used to gather information about whether it would be useful as an expert to know the patient's heart rates.

When are you able to participate?

For this user evaluation, it is important you do not have an extreme fear of spider for security purposes. This installation includes interaction with fictional spiders but may look real. In order to avoid the unpleasant or uncomfortable situation, as a result of the evaluation with augmented reality, I recommend you to NOT participate in this evaluation if you have an extreme fear of spiders. Besides that, you should be able to understand and speak the English language fluently. It is not explicitly required that you are a native English speaker but have at least a college level of English. Also if you have any impairments of hearing or vision, it is important that they are corrected by, e.g., glasses.

What will happen during the study?

After reading the information brochure, you will have time to ask questions about it or regarding the project. When you are ready to start, and you have understood everything, you will be asked to sign the informed consent.

During the evaluation, you will first do some questionnaires rating the fear of spiders. Every participant which scales on a certain level of fear will be discarded from the evaluation. While you are answering the questionnaires, the installation will be set up.

When finished with the questionnaires and determined if you are suitable for this evaluation, some instruction about the procedure will be given to you. As the last step, you will start with the evaluation by doing some challenges and afterward fill out another questionnaire.

What data will be gathered?

The main data gathered from the questionnaire before and after the evaluation will be about usage of the installation, talking about functionality, if the object is correctly implemented, etc. but also some data about the emergence of the installation, if for you it feels real. Of course, all data will be only used for this project and will remain anonymously.

What are the advantages of participation?

1. You will have the chance to get an insight of how therapy for phobia-patients works and test it.
2. You will have the chance to test gadgets on the highest technological level.
3. You will contribute to scientific research, leading to new insights.

Is your participation voluntary?

You are free to choose if you want to participate or not. Also, you can constantly ask questions about the procedure or challenges and abort at any time when feeling uncomfortable without a problem. Even if you stop the evaluation, you will be providing useful feedback.

What happens to my information?

I understand that your information is personal and I am keen on protecting you using the highest standards of protection. Your information will be stored in a secure place, according to European data protection laws and rules provided by the University of Twente Ethical board. Also, your data will absolutely not be used for promotional purposes or shared publicly.
All questionnaires will be numbered and stored separately from your personal information. During the project, you can always request your personal information at any time.

Signing the consent form

If you are sure to participate in this user evaluation, I would like to ask you kindly to sign the informed consent that I attached. With signing the consent, you declare that you have fully understood what will happen and you agree on participating.

Final remarks

The studies mentioned above are approved by the ethical committee of the Twente University. We follow the international rules and guidelines for research and data protection.

Requests regarding further information about the research, now or in the future, may be addressed to David Bel Lang on either d.s.bellang@student.utwente.nl or 004915236229393.

If you have any complaints about this research, please direct them to the Secretary of the Ethics Committee of the department of EEMCS, MW. J.M. Strootman-Baas, mail: ethics-comm-ewi@utwente.nl, tel. 053-489 6719.

Signed in duplicate:

……	……
Name subject	Signature

Appendix C: Instructions for participants & experts

Setup: Floor full with spiders

Step 1: read and sign the information brochure
Here you see an information brochure about the experiment we will be performing today. Please read it through and let me know if you have any questions or concerns.
Step 2 : read and sign the consent form
If you want to participate after reading the consent and you feel like you have no more questions, you can read and sign the consent form.
Step 3: Do SFQ
Step 4: screening for spider phobia
Step 5: Setup 1 Shared environmnt
Step 6: walk to the starting position
Step 7: when ready put on the Microsoft hololens, adjust them correctly by regulating the wheel on your backheads and wait for advise.
Step 8: analyse context, environment & interact with each other

Expert role: if you are in biofeedback group, check the heartrate

Setup: Spiders and Boxes

Step 3: change roles .
Step 4: follow the instruction given by the doctor.
Step 5: walk to the starting point .
Step 6: when ready put on the Microsoft hololens, adjust them correctly by regulating the wheel on your backhead and wait for the doctor's advice.
Step 7: search for the spiders and boxes. (tell how you feel in any moment).
Step 8: put every spider in a different box .
Step 9: take your time and only act by feeling safely.
Step 10: if you want to stop the installation say stop device or put off the hololens carefully.
Step 11: when the treatment ends, put off carefully the hololens.

Expert: Check Heart rate if you are in the group via the stream.

Appendix D: Questionnaire Lo-fi prototype

Reality

1. What was the general impression you had when you saw the spider?

2. How did the spider look to you?

3. How real did the spider feel to you?

Not real 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 Real

4. Do you think others would think this is a real spider if they saw it?

☐ Yes
☐ No

4. Could you describe the feeling generated by the spider?

5. What was the general impression you had when you saw the spider?

7. How responsive was the environment to actions that you initiated?
For example: putting the spider on top of a table.

Not responsive 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 Very responsive

8. How natural did your interactions with the environment seem?

Not natural 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 very natural

9. How natural was the mechanism which controlled movement through the environment?

10. How convincing was your sense of objects moving through space?

Not convincing at all 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 very convincing

11. How closely were you able to examine objects?

Not convincing at all 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 very closely

12. Was watching the virtual objects just as natural as watching the real world?

Yes
No,
If no explain your answer:

13. Would the implementation of sound and touch stimuli implement the sense of realism?

Yes
No
Explain your answer:

14. Did you have the impression that virtual object belonged to the real object, or did they seem separate from it?

15. Did the virtual object appear to be (visualized) on a screen, or did you have the impression that they were located in space?

16. Did you have to make an effort to recognize the virtual object as being Three-dimensional?

Do you want to add something that contributes to higher the reality level of the system?

Interaction

17. Did the installation run smoothly?

- ☐ Yes
- ☐ No

If no, explain

18. Did you have any problems grabbing the objects?

- ☐ Yes
- ☐ No

If yes, why

19. Did you get any motion sickness?

- ☐ Yes
- ☐ No

20. Was it easy to interact with the installation?

- ☐ Yes
- ☐ No

If no why not (and what would you improve on)

Biofeedback

21. Would it be helpful to see your heart rate during the test, explain your answer?

22. Do you think that if the expert sees your heart rate, he or she would better understand your situation?

- ☐ Yes
- ☐ No

23. Do you think that when you see your heart rate, you get more insight into how you are responding in this situation?

24. Do you think displaying a bumping heart would distract you from the actual challenge?

- ☐ Yes

☐ No
If no, why

25. Could seeing your heart rate make you feel uncomfortable, maybe more nervous?

General

26. How old are you?

27. What is your biological gender?

☐ Male
☐ Female

28. What kind of experience did you have with mixed reality (virtual reality & augmented reality)

29. What is your nationality

30. What is your academic level

☐ Less than a high school diploma
☐ High school degree or equivalent (e.g. GED)
☐ Some college, no degree
☐ Associate degree (e.g. AA, AS)
☐ Bachelor's degree (e.g. BA, BS)
☐ Master's degree (e.g. MA, MS, MEd)
☐ Professional degree (e.g. MD, DDS, DVM)
☐ Doctorate (e.g. PhD, EdD)

Appendix E: Questionnaire for Patients

Realism

1. How did the spider look to you?
2. What feeling did the spider generate?
3. Would you tell others that the spider looks real?

Comparison to VRET

4. Compared to the video seen before about virtual reality treatment, what treatment Showed more realism?
5. Was watching the virtual objects just as normal as watching them in the real world?
6. Would you think that AR treatment solve the main problem of VRET which is the Missing reality?
7. Do you think that this treatment is an improvement of the current VR treatment?

Experience

1. Do you prefer to have a shared environment or a single treatment supervised by the expert?
2. Did the expert bother you during the test?
3. Do you think if both interacted in the treatment it would be useful?

Biofeedback

8. Do you think the implementation of biofeedback is helpful
9. Would biofeedback give the expert a closer insight into the patient's feelings?
10. Would it be helpful for the expert, when analyzing the treatment situation?

Functionality

11. Did the system showed any problems regarding glitches, errors, etc. ?
12. Did you have any problems grabbing the objects?

General

13. What is your biological gender?
14. How old are you?
15. Did you have any previous experiences with AR?

Appendix F: Questionnaires for Experts

Questionnaire: Expert without biofeedback

1. Did the system show any problems regarding glitches, errors, etc.?
2. Did you have the feeling that the participant had any problems grabbing the objects?
3. Do you think that biofeedback (heart rate) would be helpful for the doctor?
4. Having biofeedback could you as an expert have any insight into how the patient is feeling at the moment?
5. Did you have the impression the other participant was distracted by you being in the shared environment?
6. Do you think it is useful to have a shared experience?

Questionnaire: Expert with biofeedback

1. Did the system show any problems regarding glitches, errors, etc.?
2. Did you have the feeling that the participant had any problems grabbing the objects?
3. Based on the data, do you think you would be able to understand the patient better?
4. According to the heart rate of the patient, would you change the planned treatment session?
5. Would biofeedback improve the current AR treatment?
6. Could the implementation of biofeedback distract the expert from the real task and not give a proper treatment?

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