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Inducing Phobia Response Using Virtual Reality

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Abstract

Fear is a natural reaction to dangerous situations. However, there are people who can have an irrational fear to certain things which others regard as completely safe and that is referred to as a phobia. Multiple treatments are available to those inflicted with phobias, but in recent years, virtual reality technology has become increasingly more sophisticated and thus also the interest in creating virtual environments that could induce phobias or help phobics with overcoming their fears. In this study we examined if it was possible to induce phobia reactions with virtual reality. The purpose of this study was to test the possibilities of measuring phobia responses. We created virtual environments, that each target a specific phobia. Our results show that it is possible to measure phobia responses when subjects were exposed to our virtual reality environments.

Inducing Phobia Response Using Virtual Reality

Fear is a natural physiological reaction to endangering stimuli and serves a critical function in responses necessary for survival (Fendt & Fanselow, 1999). However, when a person is inflicted with a specific phobia, this reaction is elicited to a disproportionate amount, or even by a completely innocuous stimulus, and may thus cause significant distress and difficulty (Davey, 2014). Multiple forms of treatment are available for those diagnosed with specific phobias (Choy, Fyer, & Lipsitz, 2007), but one of the more recent ones is *exposure therapy through virtual reality* (VR).

The literature on this form of exposure therapy is fairly expansive, but still very limited considering how many types of specific phobias there are (Parsons & Rizzo, 2008). Most studies have focused on one of five types of phobias: Acrophobia, agoraphobia, arachnophobia, aviophobia, and social phobia. However, two of those five (agoraphobia and social phobia) are not considered specific phobias in the DSM-5 (American Psychiatric Association, 2013) and are now categorized as separate mental disorders.

Research on treatments using exposure through VR overall show a positive outcome (Parsons & Rizzo, 2008). Studies on acrophobia reveal that VR exposure is just as effective as in vivo exposure (Emmelkamp, Bruynzeel, Drost, & van der Mast, 2001; Emmelkamp et al., 2002; Krijn et al., 2004) and in some instances even more effective (Paul M. G. Emmelkamp et al., 2001), which may in part be due to some researchers finding that VR exposure evokes more fear than in vivo exposure (Jang et al., 2002). This also applies to studies on aviophobia, with VR exposure as effective as in vivo exposure both immediately following treatment and at follow-up (Rothbaum et al., 2006; Rothbaum, Hodges, Smith, Lee, & Price, 2000). Arachnophobes managed to get on average within 6 inches of a real spider post-exposure whereas they stopped on average 5.5 feet away pre-exposure (Hoffman, Garcia-Palacios, Carlin, Furness III, & Botella-Arbona, 2003) and great progress was seen even when the treatment simply consisted of a video game (Half-Life™) including spiders instead of a software specifically made for treatment purposes (Bouchard, Côté, St-Jacques, Robillard, & Renaud, 2006).

Despite agoraphobia and social phobia not being specific phobias, the results of VR therapy on them are similar to specific phobias. VR therapy seems to be as good as Cognitive Behavior Therapy (CBT) as a treatment for agoraphobia (North, North, & Coble, 1996), if not better (Vincelli et al., 2003). However, long-term effects are not as strong after VR therapy (Choi et al., 2005). Research on social phobia show that VR therapy works as well as traditional CBT (Harris, Kemmerling, & North, 2002; Klinger et al., 2005), however, most research has only been focused on one aspect of social phobia, i.e. speech anxiety (Anderson, Zimand, Hodges, & Rothbaum, 2005; Harris et al., 2002; Klinger et al., 2005), which is in itself a specific phobia (glossophobia).

There are other phobias that can be found in the literature, but studies are often not varied enough to reach the same conclusions as the aforementioned phobias. Subjects with claustrophobia have been cured using VR and the effect of their treatment remains after at least 3 months (Cristina Botella, Baños, Villa, Perpiñá, & García-Palacios, 2000; C. Botella, Villa, Baños, Perpiñá, & García-Palacios, 1999; Malbos, Mestre, Note, & Gellato, 2008), but no study was found that compared VR to other methods of treatment. The same applies to driving phobia, VR therapy works (Wald & Taylor, 2000; Walshe, Lewis, Kim, O’Sullivan, & Wiederhold, 2003), but no study was found that compared it to another method of treatment. Research on cynophobia has shown that VR can easily bring about the arousal necessary for treatment to occur (Suied, Drettakis, Warusfel, & Viaud-Delmon, 2013; Viaud-Delmon et al., 2008), but no study was found that had the objective of treating cynophobia. The same also applies for needle phobia (B. K. Wiederhold, Mendoza, Nakatani, Bullinger, & Wiederhold, 2005), but VR is still regularly used to assist people with needle or dental phobia, but as a diversion tactic rather than a method of treatment (Hoffman et al., 2001; B. K. Wiederhold & Wiederhold, 2005).

Considering the exponential growth of technological innovation, all these results are however rather outdated. The virtual reality equipment used did not have the sort of motion-sensing options that are accessible now and many of them did not have an immersive 3D environment that the user is placed into, just computer screens. Thus, this research intends to use new and improved commercial VR products which are likely to achieve an increased sense of immersion to induce phobia response.

Approach

In order to induce phobia responses, a few different virtual environments were created. We created environments for the following phobias: Claustrophobia (the fear of confined places), arachnophobia (the fear of spiders), aquaphobia (the fear of water), aichmophobia (the fear of sharp objects), and acrophobia (the fear of heights). We also created a relaxation environment where test subjects can relax.

To bring the test subjects into the virtual environment we used the HTC Vive virtual reality headset[1]. The HTC Vive headset is developed by HTC[2] and Valve Corporation[3]. With the HTC Vive equipment it is possible to turn a room into a virtual 3D environment. The HTC Vive equipment can be seen in Figure 1 and it consists of the following parts:

[1] http://www.vive.com
[2] http://www.htc.com
[3] http://www.valvesoftware.com

Figure 1. A person with a HTC Vice headset mounted on his head. He is also holding a controller in his hand.

Two signal beacons that are put up in the corners of an environment, used by objects to know their exact position within the environment. A headset that is mounted on a person's head allowing him or her to see into a virtual world, inside of which there are two screens, one for each eye, giving the person stereoscopic vision into the 3D world. The headset is also connected to headphones allowing the person to listen to 3D sound. The position and rotation of the headset are perfectly tracked by sensors that perceive the beacons. Two handheld controllers, allowing a person to interact with the environment, are also included. The position and rotation of the controllers are also tracked.

When creating the virtual environments, we used many resources that we did not create by ourselves. These are things such as 3D models, textures and sounds. A list of these resources is provided in Appendix A.

The environments were created using the Unity game engine[4] developed by Unity Technologies. The biggest reason for us choosing Unity was our experience with Unity but it has many benefits also. Unity is a very general purpose game engine, meaning it is not geared towards any special kind of game, such as only driving games or only strategy games. It is also very cross-platform, meaning it is easy to create applications for many different platforms such as PC, web, game consoles or smartphones. It is also fairly easy to create virtual environments in Unity, that can be explored using virtual reality devices such as HTC Vive. Here are a few important Unity concepts we need to define before describing how we created the environments.

Scene

A scene in Unity is a 2D or 3D environment representing a game world. A project in Unity can contain many scenes.

GameObject

A GameObject is an object such as a 3D model, light or camera in a scene. GameObjects are organized in a hierarchical structure in the scene. GameObjects can contain other GameObjects.

Transform

Each GameObject contains an object called a Transform. A Transform contains the location, rotation and size of the GameObject.

Component

Components are a special type of object that can be added to a GameObject. Components control how GameObjects look and behave. There are many types of Components. Some are

[4] https://unity3d.com

related to the display of GameObjects. Others are related to audio, lightning, physics, networking and many other things. A GameObject that has no Components is called an empty GameObject. Such a GameObject has only a Transform.

Scripts

Scripts can be added to GameObjects as Components. A script contains code that controls how the GameObject behaves.

Prefab

GameObjects in a scene can be saved outside of the scene and they are then called prefabs. prefabs can be added to scenes in the scene editor in Unity and they will then become GameObjects in the scene. GameObjects can also be created at runtime based on a prefab.

Asset Store

Unity has an online store called asset store were users can download asset packages from. An asset package can contain various resources that can be used in Unity such as 3D models, sounds, scripts and more. In order to use HTC Vive with the application we used an asset package called SteamVR Plugin. This package contains a prefab called [CameraRig]. When this prefab is added in a scene a box appears in the scene and it is possible to experience the scene using the HTC Vive equipment. The user will see the environment as it appears from the viewpoint of the box in the scene. Each environment was created as a scene in unity.

The Relaxing Scene

Because the purpose of the phobia environments was to induce fear in the test subjects it was useful to have a relaxation environment in between the phobia scenes. There the subjects could calm themselves before going to the next phobia scene. The environment had to be as neutral as possible so it would not induce any phobia responses in the test subjects. For this purpose, we created a living room with some windows and furniture. Figure 2 shows this scene.

Figure 2. The relaxing scene is a living room environment where test subjects can relax.

The relaxing scene was created with an apartment 3D model and some furniture 3D models placed in it. The lighting for the environment is not calculated at runtime. Special ligthmaps are used to make the lightning more realistic. A ligthmap is a 2D texture containing rendered lightning for 3D models. A special dialog box is in the scene. It is the pink plane appearing in front of the chair in the picture. The test subject can interact with this dialog box using the HTC Vive controllers.

The Claustrophobia Scene

For the fear of confined places, a scene with a small room was created. The subjects sit on a chair in the room. They also sit on a chair in reality. When the subject has been in the environment for a few seconds, the walls of the room start moving closer to the chair. Eventually the subject is enclosed in a very confined space. Figure 3 shows the claustrophobia scene.

Figure 3. In the claustrophobia environment, there is a small room with a chair in it. The test subjects sit on the chair and they also sit on a chair in reality.

The claustrophobia environment is probably the simplest environment. The environment contains a chair enclosed by walls. A script is used to move the walls. The script sets the position of the walls based on the time since the scene started.

The Arachnophobia Scene

For the fear of spiders, a scene with spiders in it was created. In the scene the test subjects sit on a toilet in a small bathroom. The subjects sit on a chair in reality. Initially there are no spiders in front of the subject but after some time, spiders come crawling into the room and it is eventually filled with spiders. Figure 4 shows the arachnophobia scene.

The scene was created with some bathroom 3D models and textures. We obtained a spider 3D model with a walking animation form the Unity asset store. In the scene there are some large spiders that appear in certain locations and there are many small spiders that come into the room and end up crawling on the floor of the bathroom. A special script is used to control the movement of the small spiders on the floor.

Figure 4. A small bathroom with a toilet and a sink. As can be seen, there are spiders crawling on the floor.

The small spiders have a special RigidBody and a Sphere Collider on them which are special components in Unity. These components are used to control the movement of the spiders. The Collider component is used to hinder the spiders from walking into other objects and the RigidBody component is used to add physics behaviour to the spiders. A special script is then used to control the movement of the spiders by applying force and torque to the RigidBody Component.

The Aquaphobia Scene

For the fear of water, a scene with a natural environment was created. In the scene there is water surrounded by cliffs. Initially the test subject stands on a rock a few meters above the water. Some seconds later the water starts rising. Eventually the subjects are fully beneath the water surface. To increase immersion some water sound was added to the scene and special underwater sounds are played when the head of the subject goes under the water surface. Figure 5 shows the aquaphobia scene.

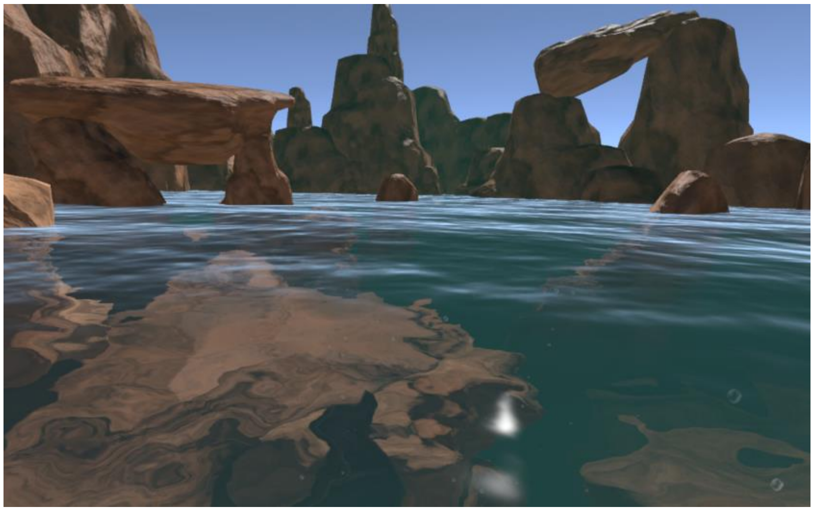

Figure 5. The aquaphobia scene has a natural environment with some rocky cliffs. The water is deep enough so the test subject can’t see to the bottom of it.

The environment in the scene was created in a similar way as the mountain scene for the acrophobia by placing rock 3D models in the right places. To create realistic water a special water shader was used. A shader is a program that runs on the GPU. The water shader used here had many input parameters and by setting the right values for the parameters the right effect could be created. A special image effect was used to create a blue green color under the water. This effect makes the water less opaque where it is deeper.

The Aichmophobia Scene

For the fear of sharp objects, a scene with a small room was created. The room has a lot of small holes in it. When the test subject has been in the room for a few seconds sharp objects start coming out of the holes in the walls. Examples of objects that appear are spears, knifes, injection needles and metal balls with spikes on them. Figure 6 shows the aichmophobia scene.

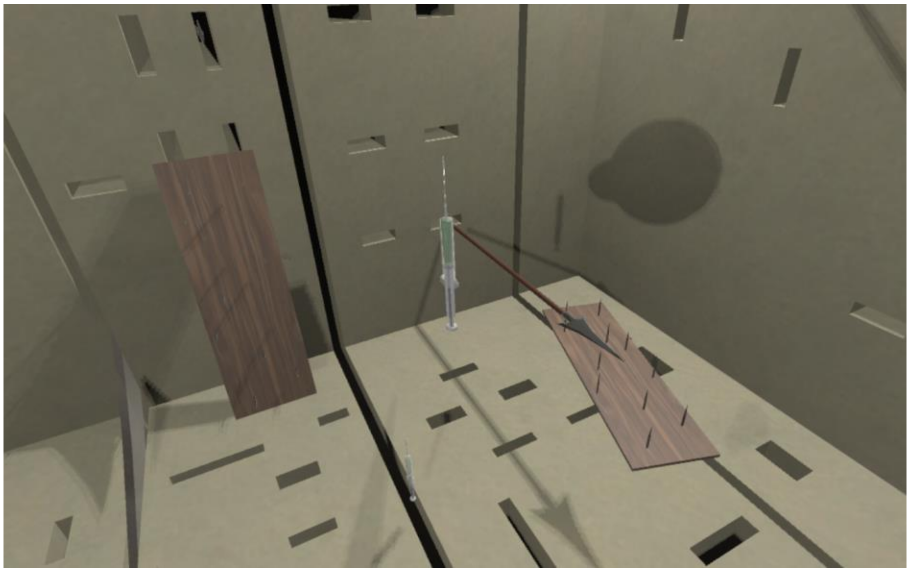

Figure 6. The aichmophobia scene has a small room with lots of holes in it. In this picture an injection needle can be seen, that comes flying upwards from a hole in the floor.

Physics simulation plays a big role in this environment. Objects that fly around the room such as knifes and needles have RigidBody components on them. In the environment there are spiky balls in chains that drop from a large hole that opens in the ceiling of the room. A special component called Hinge Joint is used to create realistic movement for the chains.

The Acrophobia Scene

For the fear of heights, a mountain scene was created. In it the test subjects walk on a wooden plank connecting two bridges between two cliffs. For greater immersion the test subjects also stand on a wooden plank in reality, as can be seen in Figure 7. In the environment there were snowflakes snowing over the bridge. A wind sound was also in the scene. For greater immersion it is possible to have a fan blowing air on the people, giving the illusion of real wind. We tried using a fan but that was not used in most of the experiments. Figure 8 shows the acrophobia scene.

Figure 7. A person with the HTC Vive equipment mounted. The person is in the acrophobia virtual environment and is walking on a plank in reality and also in the virtual environment.

Figure 8. In the acrophobia environment. In the experiment the test subjects walk on the plank connecting the two bridge parts.

The mountains in the scene were created by placing rock 3D models in the right places. Snow and clouds are created using a particle system. A particle system is a component that generates many small particles in the scene and is often used to create things such as smoke, fire and explosions.

Running the Environments

A special feature in Unity called Coroutine turned out to be very useful for controlling the flow of the scenes. It is used for the relaxation environment between phobia scenes and for the acrophobia environment. With coroutines it is easy to play sounds or write to a log file at the right time, wait for certain conditions to become true or wait for a certain period. In the code of the class InstructionController, coroutines are used in this manner.

Pilot 1

Method

Participants. Participants were sampled using a convenience sample and were all staff members of the biopharmaceutical company deCODE Genetics, Inc.

Materials.

Environments. Only the acro- and arachnophobia environments as described above were used for this experiment.

Physiological measurements. Physiological measures were obtained using technology from Nox Medical. All measures were obtained using various connections to the Nox-A1® System with SPO2: Heart rate and skin conductance were measured by connecting snap on electrodes to the Nox-AI, pulse by using an oximeter placed on the participants’ forehead, respiratory rate by connecting the Nox-AI to a Nox Abdomen Cable which measured the rise and fall of the participants' chests and abdomens, and hand movements by using the Nox-AI´s built-in tracking system. All measures were analyzed using the Noxternal™ software.

Questionnaires. A simple questionnaire was used, asking participants whether or not they had experienced acro- or arachnophobia.

Procedure. Participants were asked to remove their shoes and answer the questionnaire. Afterwards, all physiological measurement equipment was placed on them. After testing whether the equipment worked, the VR headgear and headphones were placed onto the participant.

A standing baseline was measured by having the participants stand still with no visual or auditory stimuli for 30 s and then a walking baseline was measured by asking the participants to walk over a plank in front of them. The participants did not see the plank due to the headgear. Then the acrophobia environment was turned on and the participants were asked to stand still and not look down for 30 s, then they were asked to look down for 30 s, and finally, to walk the plank which had been placed on the exact same place in space as the plank in the virtual environment.

Next, a sitting baseline was measured by having the participants sit still with no visual or auditory stimuli for 30 s. Then the arachnophobia environment was turned on.

Results

No statistical analysis was performed on the results from the first pilot, due to it mostly being a feasibility study, assessing whether there was even a possibility of finding anything statistically significant in later tests. Information from the GSR and HR measures was promising and so it was decided to conduct further research using the equipment and environments. However, the motions sensors on the arms gave very irrational output due to the amount of hand movements that the participants performed. Thus it was decided to use only one motion sensor on the middle of the chest in the next experiment rather than on the arms. Also it was decided to use electroencephalography and electrooculography in the next experiment, to increase the amount of data that could be examined.

Pilot 2

Method

Participants. Participants were sampled using a convenience sample and were all staff members of the biopharmaceutical company deCODE Genetics, Inc. The total number of participants was 16, eight of which were male and eight of which were female and their age ranged from 28 to 63 (M = 41).

Materials.

Environments. In order, the environments used were claustrophobia, arachnophobia, aquaphobia, aichmophobia, and acrophobia. In between all phobic environments as well as prior and posterior to them, participants were in a calming virtual environment resembling a living room.

Physiological measurements. Physiological measures were obtained using technology from Nox Medical. All measures were obtained using various connections to the Nox-A1® System with SPO2: Heart rate and skin conductance were measured by connecting snap on electrodes to the Nox-AI, pulse by using an oximeter placed on the participants' forehead, respiratory rate by connecting the Nox-AI to a cannula, and an electroencephalogram (EEG) was also obtained through the placement of seven snap on electrodes on the participants' forehead and temples, as well as an electrooculogram (EOG) through the placement of two electrodes under the participants' eyes. Movement was also measured through the built-in tracking system inside the Nox-AI placed on the participants' chests. All measures were analyzed using the Noxternal™ software.

Questionnaires. A simple questionnaire was used, asking participants whether or not they had experienced any of the phobias to be measured. In addition, the Simulator Sickness

Questionnaire (SSQ) developed by Kennedy, Lane, Berbaum, and Lilienthal (1993) was used to measure participants' levels of simulator sickness. The SSQ consists of 16 questions about the presence of various symptoms, such as nausea and vertigo, and participants are asked to say whether the symptoms apply to them. The answers offered are "None", "Slight", "Moderate", and "Severe". Presence was measured using three questions from the Igroup Presence Questionnaire (IPQ): "In the computer generated world I had a sense of 'being there'.", 'I was not aware of my real environment.", "How real did the virtual world seem to you?". The first two questions were answered using 5-point Likert scales ranging from "fully disagree" to "fully agree" and the last question was answered using a 5-point scale ranging from "completely real" to "not real at all".

Procedure. Participants were asked to remove their shoes and answer both the SSQ and the short questionnaire regarding their phobia responses. Then all the physiological measurement tools were placed on the participants as well as the VR headgear and the headphones while in a seated position. The participants then received prerecorded auditory instructions throughout the experiment. At first they were to remain seated for two minutes while a seated baseline was recorded. Then they entered the claustrophobia environment which ran for 60 s, after which the participants answered the three questions from the IPQ and stayed in the calming environment until they were ready to move on to the next environment. This same procedure was applied to the arachnophobia environment, except this time the baseline was only 45 seconds, after which the participants were asked to stand up. A standing baseline was gathered for 45 seconds and then the same procedure as for the earlier environments was applied to the aquaphobia environment and the aichmophobia environment (which unlike the other three environments was 75 s). Finally, participants were asked to walk over a plank in the real world which had an exact representation in the calming virtual environment, this was a walking baseline. Then when the participants were ready they entered the acrophobia environment. At first, they were asked to stand still and look around, but avoid looking down. Then the participants were asked to walk halfway over the plank and look down. Finally, they were asked to finish walking the plank and walk all the way back again. Then they again answered the three questions from the IPQ and all the tools they had on them were removed before they once again answered the SSQ.

Results

Presently, only the GSR and HR data have been analyzed, all other data is still being analyzed. No statistical analysis has been performed, all data analysis is thus visual. Both GSR and HR measures are however very promising for the arachnophobia and acrophobia environments. The claustrophobia environment also showed some promise but the aichmophobia and aquaphobia environments showed hardly any response. For most participants, those who had previously stated having a phobia of the stimulus in question showed a greater response than those who did not, increasing the validity of the environments. However, there were examples of participants who showed physiological responses as if they had a phobia despite having stated they did not and vice versa. Figures 9, 10, 11 and 12 show the ECGs from four participants, all graphs were created by deCODE Genetics, Inc. and are used here with their permission.

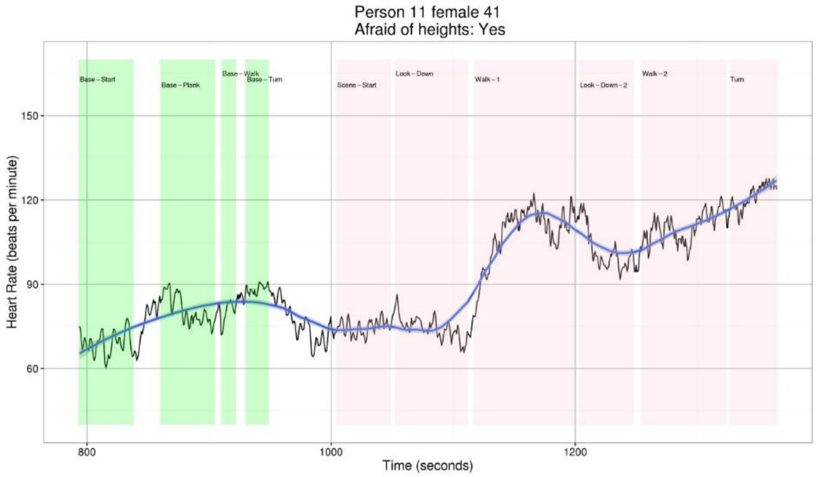

Figure 9. Heart rate as a function of time from a 41-year-old woman who is afraid of heights in the acrophobia environment. Green areas represent the relaxing environment and pink areas represent the acrophobia environment.

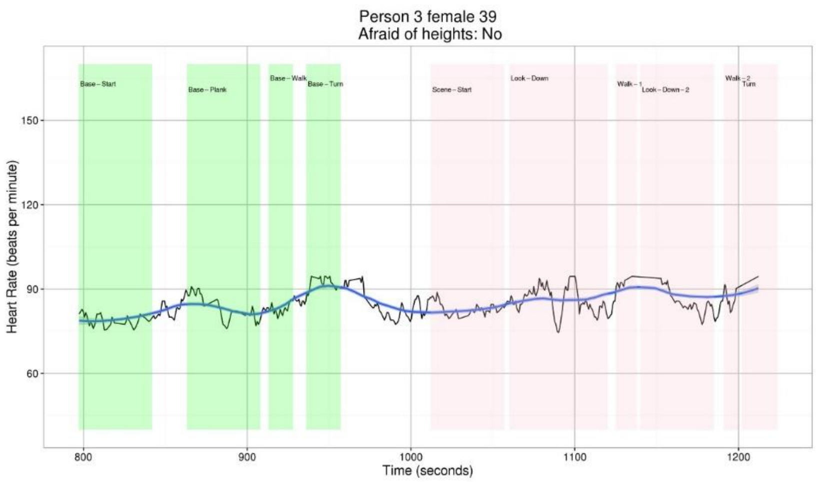

Figure 10. Heart rate as a function of time from a 39-year-old woman who is not afraid of heights in the acrophobia environment. Green areas represent the relaxing environment and pink areas represent the acrophobia environment.

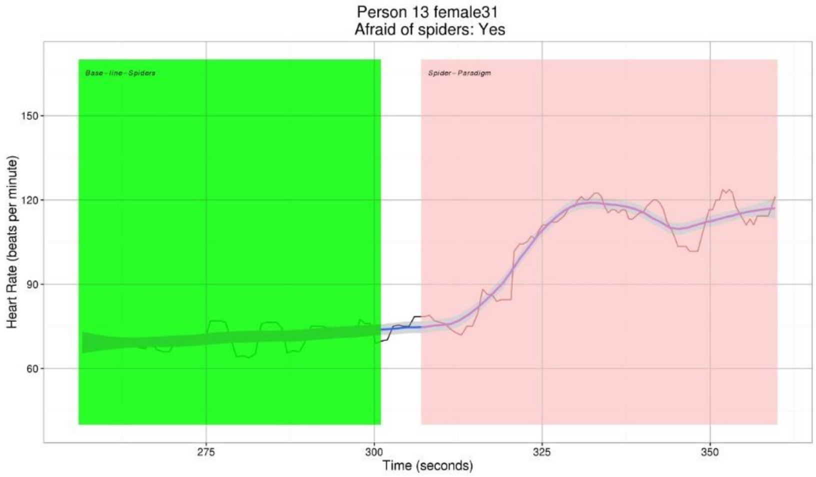

Figure 11. Heart rate as a function of time from a 31-year-old woman who is afraid of spiders in the arachnophobia environment. Green areas represent the relaxing environment and pink areas represent the acrophobia environment.

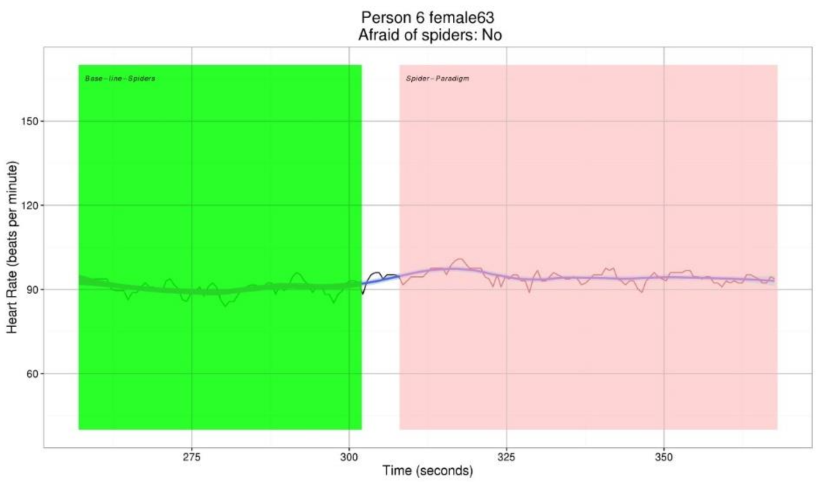

Figure 12. Heart rate as a function of time from a 63-year-old woman who is not afraid of spiders in the arachnophobia environment. Green areas represent the relaxing environment and pink areas represent the acrophobia environment.

Discussion

This study was about inducing phobia responses with virtual reality equipment and seeing if those responses could be measured. We created a few virtual environments for this purpose. As the results show, phobia responses induced with virtual reality can be measured. Data from these measurements can be used for genetic research and perhaps in other fields as well. Within a few months, deCODE Genetics, Inc. will use the arachnophobia and the acrophobia environments (as well as perhaps the claustrophobia environment if further analysis is promising) in an experiment involving about 2000 participants. This experiment will do more significant analysis on the effectiveness of the stimuli, due to their participant pool being much larger than the present one.

There are a few things that could be interesting to do in the future. Improvements could be made for the experimenter user interface. We only tested virtual environments for five different phobias so it would be interesting to create environments for other phobias and test them as well. Future work might also include creating a virtual reality application for phobia therapy.

References

American Psychiatric Association (Ed.). (2013). *Diagnostic and statistical manual of mental disorders: DSM-5* (5th ed). Washington, D.C: American Psychiatric Association.

Anderson, P. L., Zimand, E., Hodges, L. F., & Rothbaum, B. O. (2005). Cognitive behavioral therapy for public-speaking anxiety using virtual reality for exposure. *Depression and Anxiety*, *22*(3), 156–158. http://doi.org/10.1002/da.20090

Botella, C., Baños, R. M., Villa, H., Perpiñá, C., & García-Palacios, A. (2000). Virtual reality in the treatment of claustrophobic fear: A controlled, multiple-baseline design. *Behavior Therapy*, *31*(3), 583–595. http://doi.org/10.1016/S0005-7894(00)80032-5

Botella, C., Villa, H., Baños, R., Perpiñá, C., & García-Palacios, A. (1999). The treatment of claustrophobia with virtual reality: Changes in other phobic behaviors not specifically treated. *CyberPsychology & Behavior*, *2*(2), 135–141. http://doi.org/10.1089/cpb.1999.2.135

Bouchard, S., Côté, S., St-Jacques, J., Robillard, G., & Renaud, P. (2006). Effectiveness of virtual reality exposure in the treatment of arachnophobia using 3D games. *Technology and Health Care*, *14*(1), 19–27.

Choi, Y.-H., Vincelli, F., Riva, G., Wiederhold, B. K., Lee, J.-H., & Park, K.-H. (2005). Effects of group experiential cognitive therapy for the treatment of panic disorder with agoraphobia. *CyberPsychology & Behavior*, *8*(4), 387–393. http://doi.org/10.1089/cpb.2005.8.387

Choy, Y., Fyer, A. J., & Lipsitz, J. D. (2007). Treatment of specific phobia in adults. *Clinical Psychology Review*, *27*(3), 266–286. http://doi.org/10.1016/j.cpr.2006.10.002

Davey, G. (2014). *Psychopathology: Research, assessment and treatment in clinical psychology* (Second edition). Chichester, West Sussex: Wiley.

Emmelkamp, P. M. G., Bruynzeel, M., Drost, L., & van der Mast, C. A. P. G. (2001). Virtual reality treatment in acrophobia: a comparison with exposure in vivo. *CyberPsychology & Behavior, 4*(3), 335–339. http://doi.org/10.1089/109493101300210222

Emmelkamp, P. M. G., Krijn, M., Hulsbosch, A. M., de Vries, S., Schuemie, M. J., & van der Mast, C. A. P. G. (2002). Virtual reality treatment versus exposure in vivo: A comparative evaluation in acrophobia. *Behaviour Research and Therapy*, *40*(5), 509–516. http://doi.org/10.1016/S0005-7967(01)00023-7

Fendt, M., & Fanselow, M. S. (1999). The neuroanatomical and neurochemical basis of conditioned fear. *Neuroscience & Biobehavioral Reviews*, *23*(5), 743–760. http://doi.org/10.1016/S0149-7634(99)00016-0

Harris, S. R., Kemmerling, R. L., & North, M. M. (2002). Brief virtual reality therapy for public speaking anxiety. *CyberPsychology & Behavior*, *5*(6), 543–550. http://doi.org/10.1089/109493102321018187

Hoffman, H. G., Garcia-Palacios, A., Carlin, A., Furness III, T. A., & Botella-Arbona, C. (2003). Interfaces that heal: coupling real and virtual objects to treat spider phobia. *International Journal of Human–Computer Interaction*, *16*(2), 283–300. http://doi.org/10.1207/S15327590IJHC1602_08

Hoffman, H. G., Garcia-Palacios, A., Patterson, D. R., Jensen, M., Furness, T., & Ammons, W. F. (2001). The effectiveness of virtual reality for dental pain control: a case study. *CyberPsychology & Behavior*, *4*(4), 527–535. http://doi.org/10.1089/109493101750527088

Jang, D. P., Ku, J. H., Choi, Y. H., Wiederhold, B. K., Nam, S. W., Kim, I. Y., & Kim, S. I. (2002). The development of virtual reality therapy (VRT) system for the treatment of acrophobia and therapeutic case. *IEEE Transactions on Information Technology in Biomedicine*, *6*(3), 213–217. http://doi.org/10.1109/TITB.2002.802374

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology*, *3*(3), 203–220. http://doi.org/10.1207/s15327108ijap0303_3

Klinger, E., Bouchard, S., Légeron, P., Roy, S., Lauer, F., Chemin, I., & Nugues, P. (2005). Virtual reality therapy versus cognitive behavior therapy for social phobia: a preliminary controlled study. *CyberPsychology & Behavior*, *8*(1), 76–88. http://doi.org/10.1089/cpb.2005.8.76

Krijn, M., Emmelkamp, P. M. G., Biemond, R., de Wilde de Ligny, C., Schuemie, M. J., & van der Mast, C. A. P. G. (2004). Treatment of acrophobia in virtual reality: The role of immersion and presence. *Behaviour Research and Therapy*, *42*(2), 229–239. http://doi.org/10.1016/S0005-7967(03)00139-6

Malbos, E., Mestre, D. R., Note, I. D., & Gellato, C. (2008). Virtual reality and claustrophobia: multiple components therapy involving game editor virtual environments exposure. *CyberPsychology & Behavior*, *11*(6), 695–697. http://doi.org/10.1089/cpb.2007.0246

North, M. M., North, S. M., & Coble, J. R. (1996). Effectiveness of virtual environment desensitization in the treatment of agoraphobia. *Presence: Teleoperators and Virtual Environments*, *5*(3), 346–352. http://doi.org/10.1162/pres.1996.5.3.346

Parsons, T. D., & Rizzo, A. A. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry*, *39*(3), 250–261. http://doi.org/10.1016/j.jbtep.2007.07.007

Rothbaum, B. O., Anderson, P., Zimand, E., Hodges, L., Lang, D., & Wilson, J. (2006). Virtual reality exposure therapy and standard (in vivo) exposure therapy in the treatment of fear of flying. *Behavior Therapy*, *37*(1), 80–90. http://doi.org/10.1016/j.beth.2005.04.004

Rothbaum, B. O., Hodges, L., Smith, S., Lee, J. H., & Price, L. (2000). A controlled study of virtual reality exposure therapy for the fear of flying. *Journal of Consulting and Clinical Psychology*, *68*(6), 1020–1026. http://doi.org/10.1037/0022-006X.68.6.1020

Suied, C., Drettakis, G., Warusfel, O., & Viaud-Delmon, I. (2013). Auditory-visual virtual reality as a diagnostic and therapeutic tool for cynophobia. *Cyberpsychology, Behavior, and Social Networking*, *16*(2), 145–152. http://doi.org/10.1089/cyber.2012.1568

Viaud-Delmon, I., Znaïdi, F., Bonneel, N., Suied, C., Warusfel, O., Khoa-Van, N., & Drettakis, G. (2008). Auditory-visual virtual environments to treat dog phobia (pp. 119–124). Presented at the Seventh International Conference on Disability, Virtual Reality and Associated Technologies with ArtAbilitation 2008, ICDVRAT/University of Reading, UK; Retrieved from https://hal.inria.fr/inria-00606817/document

Vincelli, F., Anolli, L., Bouchard, S., Wiederhold, B. K., Zurloni, V., & Riva, G. (2003). Experiential cognitive therapy in the treatment of panic disorders with agoraphobia: a controlled study. *CyberPsychology & Behavior*, *6*(3), 321–328. http://doi.org/10.1089/109493103322011632

Wald, J., & Taylor, S. (2000). Efficacy of virtual reality exposure therapy to treat driving phobia: a case report. *Journal of Behavior Therapy and Experimental Psychiatry*, *31*(3–4), 249–257. http://doi.org/10.1016/S0005-7916(01)00009-X

Walshe, D. G., Lewis, E. J., Kim, S. I., O'Sullivan, K., & Wiederhold, B. K. (2003). Exploring the Use of Computer Games and Virtual Reality in Exposure Therapy for Fear of Driving Following a Motor Vehicle Accident. *CyberPsychology & Behavior*, *6*(3), 329–334. http://doi.org/10.1089/109493103322011641

Wiederhold, B. K., Mendoza, M., Nakatani, T., Bullinger, A. H., & Wiederhold, M. K. (2005). VR for blood-injection-injury phobia. *Annual Review of CyberTherapy and Telemedicine*, *3*, 109–116.

Wiederhold, B. K., & Wiederhold, M. D. (2005). Fear of medical procedures. In *Virtual reality therapy for anxiety disorders: Advances in evaluation and treatment* (pp. 181–188). Washington, DC, US: American Psychological Association.

Appendix A

Credits

We used many third party resources when creating the virtual environments such as 3D models, sounds and textures. Here is a list of the resources that we used in our project that we did not create ourselves.

The following Standard Assets from Unity were used

Characters

CrossPlatformInput

Effects

Environment

PhysicsMaterials

Prototyping

Utility

Files from www.1001freefonts.com

Open 24 Display - http://www.1001freefonts.com/lcd-fonts.php (by Southype)

Pocket Calculator - http://www.1001freefonts.com/lcd-fonts-2.php (by Blue Vinyl Fonts)

From the Unity Asset Store

PC Spider: https://www.assetstore.unity3d.com/en/#!/content/26543

Old Bridge: https://www.assetstore.unity3d.com/en/#!/content/33888

Fishing Boat: https://www.assetstore.unity3d.com/en/#!/content/23181

Rock & Boulders: https://www.assetstore.unity3d.com/en/#!/content/2452

Modular Wooden Bridge Tiles: https://www.assetstore.unity3d.com/en/#!/content/29501

Mobile Planes: Small Passenger Plane: https://www.assetstore.unity3d.com/en/#!/content/56690

Tents: https://www.assetstore.unity3d.com/en/#!/content/21461

SteamVR Plugin: https://www.assetstore.unity3d.com/en/#!/content/32647

Bathroom Props: https://www.assetstore.unity3d.com/en/#!/content/25255

Tiles - Bathroom 01 Tiles 01: https://www.assetstore.unity3d.com/en/#!/content/48479

Lightning Bolt Effect for Unity - https://www.assetstore.unity3d.com/en/#!/content/59471

Nature Starter Kit 2 - https://www.assetstore.unity3d.com/en/#!/content/52977

Park Chair - https://www.assetstore.unity3d.com/en/#!/content/850

Gem Shader - https://www.assetstore.unity3d.com/en/#!/content/3

Paintings Free - https://www.assetstore.unity3d.com/en/#!/content/44185

Piano - https://www.assetstore.unity3d.com/en/#!/content/154

Yughues Free Decorative Plants - https://www.assetstore.unity3d.com/en/#!/content/13283

Books Pack - https://www.assetstore.unity3d.com/en/#!/content/5484

Flatscreen TV - https://www.assetstore.unity3d.com/en/#!/content/9721

Clock - https://www.assetstore.unity3d.com/en/#!/content/4250

Chest of Drawers - https://www.assetstore.unity3d.com/en/#!/content/58835

Free Furniture Pack 1 - https://www.assetstore.unity3d.com/en/#!/content/11859

MK Glow - https://www.assetstore.unity3d.com/en/#!/content/28044

Old Wooden Row Boat v2 - https://www.assetstore.unity3d.com/en/#!/content/780

Jiggly Bubble Free - https://www.assetstore.unity3d.com/en/#!/content/61236

Old Armchair - https://www.assetstore.unity3d.com/en/#!/content/33205

Hospital Horror Pack - https://www.assetstore.unity3d.com/en/#!/content/44045

Files from www.freesound.org

https://www.freesound.org/people/Rollo145/sounds/320555/ - Door Creaking (by Rollo145)

https://www.freesound.org/people/spookymodem/sounds/202108/ - Spider Chattering (by spookymodem)

http://freesound.org/people/Benboncan/sounds/67884/ - Lake Waves (by Benboncan)

http://freesound.org/people/Owl/sounds/234054/ - Grisslehamn Waves and gulls Long (by Owl)

http://freesound.org/people/dio_333/sounds/243955/ - Waves Barcelona Calm by (by dio_333)

http://freesound.org/people/kangaroovindaloo/sounds/138288/ - Desert at Night (by kangaroovindaloo)

http://freesound.org/people/suonho/sounds/17726/ - Elements Water Underwater (by suonho)

http://freesound.org/people/akemov/sounds/255597/ - Underwater Ambience (by akemov)

http://www.freesound.org/people/Proxima4/sounds/104319/ - Desert Monolith (by Proxima4)

http://freesound.org/people/a-row/sounds/157007/ - Wind-ESP-Monophonic-synth (by a-row)

http://freesound.org/people/Sandermotions/sounds/234306/ - Forrest field spring sounds (by Sandermotions)

http://freesound.org/people/kangaroovindaloo/sounds/205966/ - Medium Wind (by kangaroovindaloo)

http://freesound.org/people/InspectorJ/sounds/343130/ - Ticking Clock (by InspectorJ)

http://www.freesound.org/people/genel/sounds/131552/ - door (by genel)

http://www.freesound.org/people/tompallant/sounds/208721/ - Wardrobe_Sliding_Door_Slow_001.aif (by tompallant)

https://freesound.org/people/crcavol/sounds/154634/ - Dropping_Knife_Linoleum.aif (by crcavol)

https://freesound.org/people/Mediapaja2009/sounds/162560/ - Drawing sword (by Mediapaja2009)

http://www.freesound.org/people/yottasounds/sounds/174458/ - cave wind 10.wav (by yottasounds)

http://www.freesound.org/people/freemaster2/sounds/172351/ - Craft interior ambience (by freemaster2)

http://www.freesound.org/people/Corsica_S/sounds/106398/ - train tunnel.flac (by Corsica_S)

http://www.freesound.org/people/Electroviolence/sounds/234537/ - Wind Tunnel (by Electroviolence)

http://www.freesound.org/people/Cell31_Sound_Productions/sounds/215168/ - Wind_Whistling_Tunnel.wav (by Cell31_Sound_Productions)

http://www.freesound.org/people/spookymodem/sounds/202098/ - Falling Rock.wav (by spookymodem)

http://www.freesound.org/people/spanrucker/sounds/272218/ - Pan Pot Wok Metal Glass Dish Lift Cupboard (by spanrucker)

http://www.freesound.org/people/jorickhoofd/sounds/160045/ - Metal hit with metal bar resonance (by jorickhoofd)

http://www.freesound.org/people/RoganDerrick/sounds/260434/ - Glass Break - Medium Jar (by RoganDerrick)

http://freesound.org/people/FreqMan/sounds/25864/ - Fluorescent Lights Shutting Down (by FreqMan) http://freesound.org/people/pfranzen/sounds/328013/ - Irritating Fluorescent Light Hum (by pfranzen)

http://freesound.org/people/patchen/sounds/20190/ - Breezy City Amb (by patchen)

http://freesound.org/people/unfa/sounds/244266/ - unfa's Menu Sounds (by unfa)

http://freesound.org/people/Snapper4298/sounds/178186/ - camera click_NIKON (by Snapper4298)

Used content from the tool MAKEHUMAN

http://www.makehuman.org/