SPECTRUM OF REALITY

Sjoerd Aendekerk
Eindhoven, The Netherlands
s.w.m.aendekerk@student.tue.nl

Hai Lam Ha
Eindhoven, The Netherlands
h.l.ha@student.tue.nl

Thijs Reijnders
Eindhoven, The Netherlands
t.j.e.reijnders@student.tue.nl

Luke Smit
Eindhoven, The Netherlands
l.smit@student.tue.nl

ABSTRACT
In this research paper, we define several design implications that could be considered when designing Virtual Reality environments for stress relief, based on the performed study. The paper describes our preliminary research and questionnaire and explains our findings from these. We also go into more detail about our environments, study, and the results thereof. Lastly, we share design implications that can be derived from this data, with these being divided into four distinct topics: audio, interactions, visual quality, and immersion. Also provided are simple ideas for how we believe these implications could be implemented in wider VR stress relief applications and software technologies.

Author Keywords
Virtual Experience; Spectrum of Reality; Realism; Abstract; Nature; Audio; Visual; Stress Relief

Word Count
4529

INTRODUCTION

In today's fast paced academic environment, students experience high levels of stress. Students often experience stress, due to deadlines, or for example right before a test or an important presentation. Our preliminary research, a questionnaire among students, confirms this.

From the preliminary research we conducted, it has shown that most students have stressful experiences. That is why we wanted to see how virtual reality could possibly help with stress reduction. What we quickly found was that there are already a lot of options using virtual reality in combination with meditation and stress relieving methods. Something we noticed was that most of these apps don't have an explanation for their usage of certain visuals and audio. That's how we came to our research question:

"How does the spectrum of reality affect the stress reduction of students in a virtual experience?"

The spectrum of reality refers to what degree a virtual experience mimics the real world. This can be both in terms of visuals or audio. On this spectrum, one end represents realistic environments while the other end embodies abstract environments.

We define abstract environments as those composed of basic geometric shapes that are not easily recognizable. In contrast, we view realistic environments as those that closely resemble nature, such as a forest during the daytime.

Through this research, we aim to understand how different points on this spectrum impact stress reduction in students, potentially guiding the development of more effective VR stress relief tools.

RELATED WORKS

During the preliminary stages of this project, we performed several accounts of research-gathering and literature reviews. This research forms the basis for our study's methods and hypotheses.

Virtual Reality (VR) technology has shown a high *"potential in improving and regulating emotional well-being"* [19]. Within the virtual reality (VR) scene, many games and applications have been developed to reduce stress. For instance, DEEP VR [23] is a good example of a VR game that focuses on breathing techniques to relieve anxiety and stress. Set in a soothing underwater environment, this game provides a solid virtual relaxation experience. Another excellent example is PLAYNE [27], a VR app that emphasizes meditation. By encouraging daily meditation practice, PLAYNE allows users to transform their calming natural environment, fostering the creation of a daily meditation habit.

Several studies on stress reduction highlight techniques such as relaxation training and breathing exercises [10, 21]. These studies often utilize realistic environments. While these games and apps offer effective systems for managing stress and anxiety through auditory and visual elements, they often don't explain why these specific elements are relaxing or why particular environments were chosen. This presents an opportunity for us to research the factors that make virtual reality environments conducive to relaxation.

Audio

Music does have a big impact on the relaxation of individuals and reducing their stress levels. [25] However, s important to note that the type of music and the goal of the listening experience has a big influence on the outcome of these effects. [14] Lower-tempo music and nature sounds are the best to listen to when experiencing stress, think of classical music and bird sounds. Also choosing your own

music for relaxation seems to improve the effects. On the other hand, sitting in silence while stressed or lisenting to high-paced music, like heavy metal, can negatively influence an individual. [12, 28] Most of these researches are done within an in-lab setting, but different researches show that it is also applicable in a daily life setting. [15] Within our research project, it is thus important to select relevant music and sounds for relaxation that apply to the majority of the participants, this can be done through a survey or interview.

Visuals

There are a high number of research papers on the influence of visuals in stress relief, many of which analyse the effects of nature scenes on stress relief. We found that a number of these studies compare their resulting stress relief data with data gathered from parallel interactions in a physical forest [4, 16, 22, 24]. Other papers and studies we could find provided comparable results, and, while these do not compare their stress data with real-life situations, these VR experiences were primarily based on realistic environments [1, 6, 9–11, 18, 21]

Realistic environments are present in every paper, with the most common being forests, urban settings, and underwater scenes. From these environments, effectively all papers conclude that forest or equivalent nature scenes have the greatest influence on positive stress reduction. This is in line with pre-existing research on the effect of nature on cognition and stress reduction. [17, 29] However there is a significant lack of research into other types of visual environments such as stylized and abstract.

Interaction

Games and exercise both play significant roles in reducing stress and enhancing overall well-being. Games reduce stress by giving the player a sense of accomplishment and self-assurance. When players get into the 'flow', they feel a sense of elation and a deep sense of pleasure that can be remembered as a milestone in their lives. [8]

Exercise, on the other hand, helps reduce stress through its immediate impact on energy, calmness, and tiredness levels. As little as five minutes of walking can be mood-elevating, but there is general agreement that a minimum of 20 to 30 minutes of exercise is needed to generate significant psychological benefits.[2] The longer the exercise, the greater the benefits. Social exercise specifically improves the stress-reducing benefits of exercise, as calmness increases more significantly after exercising with someone compared to exercising alone. [20]

METHODOLOGY

For this research, a combination of qualitative data and quantitative data is used. This data is used in order to define design implications for future designers and designs.

The research consisted of a virtual reality experience using the Meta Quest 3 [30] and an interview, throughout the research the heart rate of participants was measured using a Fitbit Inspire 3 [31]. The heart rate provides objective and quantitative data that correlates with the body's stress response. This allows us to assess the impact of the VR-environments on the stress levels. Three virtual reality worlds were created in Unreal Engine 5 [32]: a realistic world, an abstract world and a mixed world. [33] Three virtual reality worlds were created in Unreal Engine 5: a realistic world, an abstract world and a mixed world.

A total of 36 participants took part in the research, 12 participants for each world. We chose this amount because heart rate from person to person can differ a lot, by having a larger group of people we are able to get a more reliable average in heart rate data and feedback on the experience. The amount of participants was chosen together with our research coach. For every session, two researchers were in the room together with the participant. The researchers chosen for each session did not have a connection with the participants and were complete strangers to one another, in order to prevent bias. Because the researchers are strangers to the participants, it might induce some kind of stress, this side effect works in favor of the research.

Before the experience participants were asked 3 questions about their current stress levels and frequency, participants could answer using a Likert scale, these questions can be found in appendix A. Following is a 3 minute virtual reality experience in one of the worlds, without any distraction from the outside world. For this a 3 minute experience is chosen, this was chosen based on feedback from a pilot run and literature review about short relaxation experiences [6] After the 3 minutes are over, the participants are interviewed about their experience, these questions can be found in appendix A.

At the end of this interview, participants were asked if they would like to experience the opposed virtual experience, which is the realistic one for the abstract experience and vice versa. Participants who experience the mixed world, were given the option to experience the realistic world. If participants agreed, they would in the end be asked if they would prefer this world over the other and why.

As said before heart rate data was measured during the session. The Fitbit measured participants' heart rates at 5-second intervals, with measurements recorded in beats per minute (bpm). This data was analysed using repeated measures ANOVA to test our hypotheses, this method allows us to better analyse our participants heart rate changes over time:

Null hypothesis H0: There is no significant difference in the average heart rate of participants across the realistic, abstract, and mixed VR environments.

Alternative hypothesis H1: Participants in the realistic VR environment will have a higher average heart rate compared to those in the abstract and mixed VR environments.

The qualitative data from interviews was analysed using the Thematic Analysis method, we chose this method because it is flexible, transparent, applicable to large data sets and its ease of use. All answers were coded, and later grouped into themes.

This research was done in compliance with the minimal risk checklist, which was approved by the Ethical Review Board. Each participant was asked to sign a informed consent form before the research took place, the informed consent form can be found in Appendix A

Design

As mentioned in the previous section, we created three distinct worlds for this research.

The realistic world (figure 1) consisted of both visual and auditory elements from nature. The scene consisted of trees, grass, a small lake and rocks, auditory elements consist of flowing water and chirping birds in combination with classical music. The decisions to use these specific visuals and audio for the realistic world is based on other studies, which can be found in the related works [28]

For the abstract world (figure 2), green floating bubbles, with green floating particles and a green hilly landscape was created. For the audio a futuristic ambient soundscape was used, which consisted of synthesizer sounds. This audio was considered as abstract, as it deviates from traditional music forms, uses electronic sounds which are manipulated by the synthesizer. Because of its exploratory and experimental approach, the audio does not adhere to conventional musical expectations, which in our eyes can be seen as abstract. [34]

The abstract scene is designed so that it resembles the realistic world in an abstract way, trees are for example replaced by clouds of sound reactive particles, while the water is replaced by glowing floating particles. The green theme was chosen as it is the most dominant color used in the realistic world, this was done to rule out influences from other variables as much as possible.

The mixed world consisted of a combination of visuals from the abstract world and audio from the realistic world. This mixed scene is made to test the congruence and potential effects of visuals and audio.

The goal of all worlds is not to be interactive, it is meant to be an audio visual experience. The audio visual experience was chosen because of preliminary research, as these elements were most commonly used by participants to relief stress. (related works sources)

Figure 1, realistic virtual reality world

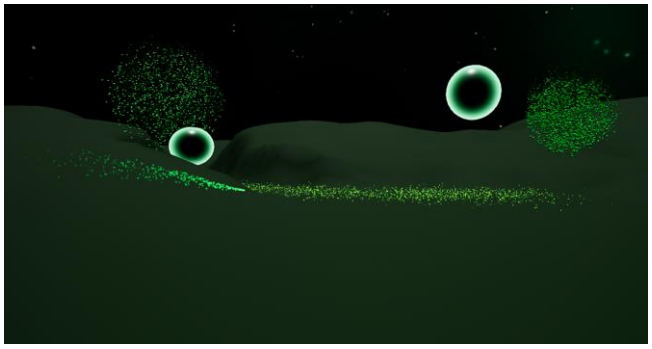

Figure 2, abstract virtual reality world

RESULTS

In our research, we examined the impact of virtual reality (VR) environments on participants' stress levels by measuring their heart rates using Fitbit Inspire 3 devices. We conducted both quantitative and qualitative analyses to understand the effects of these VR experiences.

Quantitative Analysis

As a quantitative indicator of participants stress levels we measured their heart rate using Fitbit Inspire 3. Jupyter Notebook was used to prepare, visualize and evaluate the heart rate data for better understanding.

Individual

Each participant’s heart rate data was visualized in multiple graphs. The first set of graphs illustrates the heart rate during the entire interview, with the VR-environments highlighted in their respective colours. Additionally, a Gaussian filter was applied to better show the de- or increase of the heart rate (Figure 3).

These graphs revealed that multiple participants’s heart rate decreased during the experiences, but after the experience the heart rate increased again. These peaks were often higher than before the experience. Another reoccurring theme was the increase in heart rate during the experience.

The second set of visualizations showcases the average heart rate before, during and after the 3-minute experience (Figure 4). This timeframe was chosen to make sure there were equal amounts of datapoints to compare the heart rate data. These graphs were used to understand the impact of the experience on the heart rate.

From these visualizations there are four distinct heart rate patterns we can recognize: Low-High-Low, Low-High-High, High-Low-High and High-Low-Low (Table 1). Counting the occurrences of each pattern per theme revealed some surprising results.

The desired outcome of the graphs would be the High-Low-High or High-Low-Low showing a reduction in the average heart rate during and/or after the virtual experience. Though 21 out of the 36 participants show an increase during and/or after the virtual experience. Another interesting result is that each VR- environment has a different ratio of desired and undesired outcome.

Combined

After evaluating the results of the participants individually the data was prepared to evaluate the combined average.

The timestamps of the start and end of the experience for each participant were used to filter the data. The participants were group based on their VR-environment. To synchronize the timing, the datetime was converted to a timer. Since the data of participants are being collected in intervals of 5, 10 or 15 seconds the datapoints don't match up. To fix this the data was interpolated to provide values for each second. The 12 participants of each VR-environment were combined into an average for each of the VR-environments. An additional column for the heart rate difference was added to align the heart rate of the environments. This way we can properly compare the graphs of the environments visually. This data frame was then visualized in Figure 5.

An repeated measures ANOVA was performed assessing the difference in average heart rate across the realistic, abstract and mixed VR-environments. The results of the repeated measures ANOVA (F-value 0.9876, p-value: 0.4258) show that we aren't able to reject the Null Hypothesis. Thus, there is no significant variation in heart rate difference among the different VR-environments.

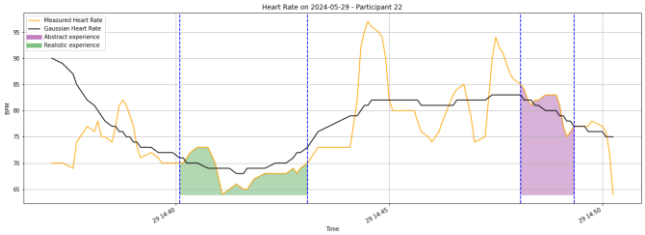

Figure 3, Graph of heart rate during the study – Participant 22

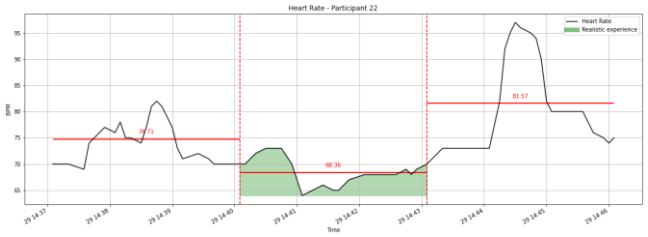

Figure 4, Graph of average heart rate before, during and after experience – Participant 22

Table 1, Heart rate patterns per VR-environment

VR-environment	Realistic	Abstract	Mixed	Total
Low-High-Low /\	3	6	1	10
Low-High-High /	3	4	4	11
High-Low-High \/	5	2	4	11
High-Low-Low \	1	0	3	4

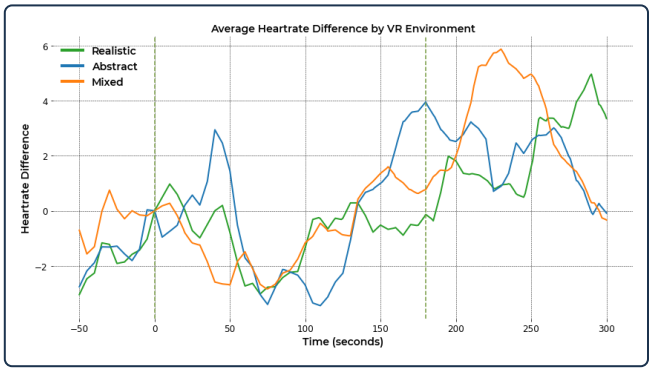

Figure 5, Graph of Average Hearthrate Difference between the different environments

Qualitative Analysis

Next to the obtained heart-rate data we also gathered information and feedback from our interviews. To define design implications for further research and design of virtual experiences and games, we did a thematic analysis [5] of the interview answers. This analysis helped us define different reoccurring themes in the interviews.

Music

The most recurring theme throughout our research was music. Most people found that this was the element that helped the most with the relaxation in the virtual experience. One participant stated: *"Audio helps more than visuals because it might make it more difficult to think about other things. With music on to focus, it makes it harder to worry about things."* This is in line with our preliminary research about the relaxing effects of audio [28]. The participants also stated that there was no difference between the abstract and the realistic audio since they both had a calming feel to them.

Nature Sounds

Most of the participants who experienced the realistic environment noticed the subtle nature sounds added in the background. *"The bird and wind sounds make it feel like real life"*. It enhanced their feeling of being in a realistic natural environment. When experiencing the mixed environment, although there were no realistic visuals, participants still found the nature sounds calming. They often perceived the particles as resembling a flock of birds because of the sounds, enhancing their relaxing experience.

Nature and Greenery

Within the realistic experience, the majority of participants considered the nature and greenery visuals very pleasant. *"The plants were moving and lively but felt recognizable and calming."* This connects with our preliminary research that stated that people feel calm and relaxed when being in a natural or green environment. [16]

Uncanny Valley

reoccurring theme within the realistic experience was the Uncanny Valley effect. This is the uncomfortable feeling people get when something looks almost, but not quite, human. [26] The participants stated that it "feels like the Uncanny Valley effect, you can see that it is not fully realistic" *and that it is* "realistically recreated but graphics are not completely realistic"*. So while the participants in general liked the realistic experience, the lack of high-quality visuals made it feel like it was not fully real.*

Interactions

During our research, we noticed that most of the participants stated that *"at some point, it got a bit boring"* and that *"some interaction could make it interesting for longer."* Because our experiences were static, meaning that the participants could only stand and look around, the participants did not experience the environments as interesting anymore after some time, reducing the effectiveness of the experience. In the abstract and mixed experience, we did have a particle flying around the environment, making it slightly more interesting than the fully static realistic experience, because they could *"follow the ball that went around."* Because of this, most participants found that something unpredictable or interactive could be good to implement to keep attention in the virtual environment.

Immersiveness and Visuals

Some participants found that the environments were relaxing because *"you are taken away from the real world for a moment"* which felt like *"you lost all stressful thoughts for a moment"*. This means that for them it was important that they felt like they were in another world. They stated that this mostly was in the case of the abstract experience and mixed experience, which had the abstract visuals, because this was a more fantasy and outer-world environment with flying particles and bubbles, creating better immersion.

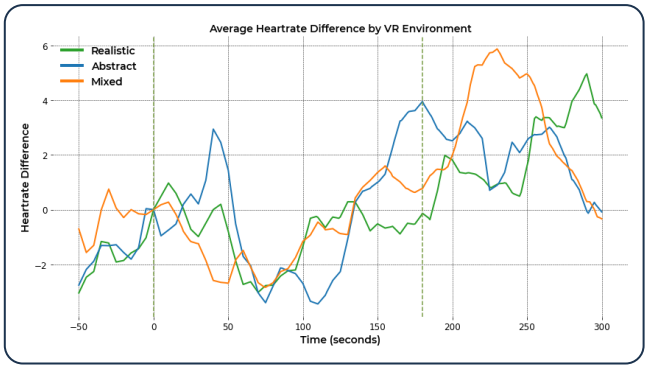

Figure 6: Graph of Average Hearthrate Difference between the different environments

Interesting Findings

When analyzing the interviews and looking back at the graphs we found some intriguing explanations for the interesting patterns in the graph (figure 6). In this graph, we see that in the beginning, the heart rate difference increases and then quickly reduces, at last around the halfway mark the heart rate difference starts to increase again.

By analyzing the increase in heart rate at the beginning of the graph we found that participants had to take some time to adjust to their new environment. They stated that *"After some time you get into the atmosphere/environment"* and then they start to feel more relaxed.

What was interesting to see is that there is a period of relaxation which is an explanation for the trough in the graph. Although our data analysis shows that there is no large variation in heart rate difference, most participants did experience the environments as relaxing or calming. They stated that: *"It did give a feeling of peace because you are put in a different world, which distracts from the real world"* and *"I actually became calm over time"*. Meaning that for some time they indeed experienced slight relaxation.

From the thematic analysis, we can also explain the increase in heart rate difference towards the end of the graph. Most participants stated that they felt bored after one and a half to two minutes. They described *"The experience was calming in a way, until the point where I realized I was*

not actually there and had a mask on. Once mapped out, I started tapping back into reality." This explains the increase, because the participants became bored, due to the lack of interaction, they started to go back to their stressful thoughts and thus felt more stressed and had an increased heart rate.

CONCLUSION

Although the results of our data analysis show no significant difference in stress reductive effects among the three experiences, we can still deduct noteworthy conclusions from our research. By analyzing the interesting patterns in our graphs and combining them with our interview analysis, we propose four design implementations for future research and design of virtual experiences and games:

1. *Audio*

Audio is the most important component for relaxation since it enhances the sensation of being in another world or reality. Most games nowadays build the visuals of the game and then add audio to support the visuals. However, we discovered that for stress-relieving games and experiences, designers should do the opposite and create visuals to support the audio.

2. Interactions

The graphs clearly show that after one and a half to two minutes, the heart rate begins to rise again. We discovered that most participants became bored after this time, so they returned to their thoughts and became stressed again. For an effective stress-reduction experience, designers should create relaxing experiences that are both interactive and engaging.

3. Visual Quality

The visual quality of the experience is essential. Specifically for our realistic experience, participants noticed that while it was visualizing a realistic environment, they could still see the graphics, creating an Uncanny Valley effect that took away from the experience. So, when selecting a theme, such as realism or abstraction, designers must ensure that the visuals support the theme. For instance, if the visuals are intended to be realistic, designers must make them as close to reality as possible; when the visuals do not precisely resemble their intended purpose, it can cause alienation and discomfort.

4. Immersion

Our research found that immersion is crucial. The experience should be fully immersive, using audio, visuals, and interaction to disconnect users from the real world. There are two types of immersion: complete immersion (like VR) and psychological presence, which relies on interaction to be maintained. [35] Designers should aim to limit possible external stimuli and create an experience that allows for both complete immersion and presence into another world through audio, visuals, and interaction.

DISCUSSION

In this section, we will discuss the limitations of this research and suggest potential directions for future work.

Limitations

There are a few limitations in this research, which if touched upon earlier could have made this research better. First of all, the limitations of the heart rate. Heart rate is a variable that can differ a lot from person to person, heart rate can fluctuate a lot in a short or longer time span, not only because of stress, but also because of other factors like physical activity or even the temperature. [33] A physically active person might have a lower starting heart rate than another person. Some participants might also find it more nerve wrecking to meet new people (researchers) than others, this can also influence the heart rate during the research.

The target group for this study are students. However students are very different from one another, and so is there method for relaxation. This virtual reality experience can be seen as one of the many methods for relaxation or stress relief. We as researcher have not looked at whether they would prefer this virtual reality experience over other relaxation methods, we laid our focus on the difference between the virtual reality experiences. Some groups might not prefer this method, which means that their answers might not be as meaningful as those of someone who would use this method of stress relief. The goal for the use of the virtual reality experience must also be taken into account, for some participants it makes them excited, for some it felt like they wanted to sleep. Each participant will use the experience differently, in this research we asked general questions about their experience, by asking more about how they would use and what they would do in the virtual world more interesting design implications can be gained.

There is also the potential bias of the nature visuals in the realistic experience. Nature is seen by most as an relaxing environment, this does not mean that it is the case for everyone. This potential bias means that they would automatically not like this environment for relaxation. Also by telling the participants who like nature as a means to relief stress that they would be put in a natural environment will affect the results, as they will automatically expect that the nature scenes will soothing. Some participants even said that they would rather go outside, than putting on a VR headset.

Lastly the differences between the worlds, as researchers we tried to remove as much variables as possible between the two worlds, however there will always be things that will be different. We tried to make an abstract world of our realistic world, which means that elements from the realistic world needed to be resembled abstractly, but what is abstract, something abstract is not just something that can be easily visualized. For most of our participants our world was abstract, however there were also some participants who did not find it completely abstract, they mentioned that

there are still recognizable elements which can be connected to a realistic world. By eliminating these elements or giving more thought into making an accurate abstract world, would make the difference between the two worlds bigger. Our realistic world could also be improved a lot, by making it ultra-realistic, however due to hardware limitations we were not able to do this.

Future works

Something that could be done for future research is implementing the Trier Social Stress Test (TSST) before the virtual experience. This method will induce temporary stress for the participant. This method can make sure that participants are verifiably stressed before the experience, instead of it being dependent on the participant. By using this method a better/more accurate representation of data will be gained. We proposed this method to the Ethics Review Board of the TU/e, however this was met with a lot of complications.

Future work could also include different methods of stress measurement, in this research only heart rate and qualitative data is being taken into account. But these are not the only ways to measure stress, the use of cortisol levels, blood pressure and electrodermal activity can be taken into consideration when doing this research. [3, 7, 13] The combined use of these methods will allow for more accurate stress detection and analysis

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In this report AI like ChatGPT and Grammarly where used to improve and check grammar.

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REFERENCES

[1] Ágnes Karolina Bakk, Borbála Tölgyesi, Máté Barkóczi, Balázs Buri, András Szabó, Botond Tobai, Iva Georgieva, and Christian Roth. 2023. Zenctuary VR: Simulating Nature in an Interactive Virtual Reality Application: Description of the design process of creating a garden in Virtual Reality with the aim of testing its restorative effects. In *Proceedings of the 2023 ACM International Conference on Interactive Media Experiences* (*IMX '23*), August 29, 2023. Association for Computing Machinery, New York, NY, USA, 165–169. https://doi.org/10.1145/3573381.3597215

[2] Bonnie G. Berger. 1994. Coping With Stress: The Effectiveness of Exercise and Other Techniques. *Quest* 46, 1 (1994), 100.

[3] Wolfram Boucsein. 2012. *Electrodermal Activity*. Springer US, Boston, MA. https://doi.org/10.1007/978-1-4614-1126-0

[4] Matthew H. E. M. Browning, Katherine J. Mimnaugh, Carena J. Van Riper, Heidemarie K. Laurent, and Steven M. LaValle. 2020. Can Simulated Nature Support Mental Health? Comparing Short, Single-Doses of 360-Degree Nature Videos in Virtual Reality With the Outdoors. *Front. Psychol.* 10, (January 2020), 2667. https://doi.org/10.3389/fpsyg.2019.02667

[5] Victoria Clarke and Virginia Braun. 2014. Thematic Analysis. In *Encyclopedia of Quality of Life and Well-Being Research*, Alex C. Michalos (ed.). Springer Netherlands, Dordrecht, 6626–6628. https://doi.org/10.1007/978-94-007-0753-5_3470

[6] Huner Erdinc. Watching a nature video improves negative affect and stress but does not change positive affect. Retrieved March 26, 2024 from https://steve.psy.gla.ac.uk/myNewWave/HunerErdinc.pdf

[7] Dirk H. Hellhammer, Stefan Wüst, and Brigitte M. Kudielka. 2009. Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology* 34, 2 (February 2009), 163–171. https://doi.org/10.1016/j.psyneuen.2008.10.026

[8] Hsiao-shen Wang, Chien-Yu Liu, and Min Tseng. 2022. Playing Puzzle Games to Reduce College Students' Pressure. *US-China Educ. Rev. A* 12, 5 (October 2022). https://doi.org/10.17265/2161-623X/2022.05.006

[9] Jorien de Jonge. The effect of music, nature visuals and sounds on induced anxiety.

[10] Dorota Kaminska, Krzysztof Smolka, Grzegorz Zwolinski, Slawomir Wiak, Dorota Merecz-Kot, and Gholamreza Anbarjafari. 2020. Stress Reduction Using Bilateral Stimulation in Virtual Reality. *IEEE Access* 8, (2020), 200351–200366. https://doi.org/10.1109/ACCESS.2020.3035540

[11] Y.A.W. de Kort and W.a. Ijsselsteijn. 2006. Reality Check: The Role of Realism in Stress Reduction Using Media Technology. *Cyberpsychol. Behav.* 9, 2 (April 2006), 230–233. https://doi.org/10.1089/cpb.2006.9.230

[12] Elise Labbé, Nicholas Schmidt, Jonathan Babin, and Martha Pharr. 2007. Coping with Stress: The Effectiveness of Different Types of Music. *Appl. Psychophysiol. Biofeedback* 32, 3 (December 2007), 163–168. https://doi.org/10.1007/s10484-007-9043-9

[13] Fiona M. Laird, Huaibin Cai, Alena V. Savonenko, Mohamed H. Farah, Kaiwen He, Tatyana Melnikova, Hongjin Wen, Hsueh-Cheng Chiang, Guilian Xu, Vassilis E. Koliatsos, David R. Borchelt, Donald L. Price, Hey-Kyoung Lee, and Philip C. Wong. 2005. BACE1, a major determinant of selective vulnerability of the brain to amyloid-beta amyloidogenesis, is essential for cognitive, emotional, and synaptic functions. *J. Neurosci. Off. J. Soc. Neurosci.* 25, 50 (December 2005), 11693–

11709. https://doi.org/10.1523/JNEUROSCI.2766-05.2005

[14] Alexandra Linnemann, Beate Ditzen, Jana Strahler, Johanna M. Doerr, and Urs M. Nater. 2015. Music listening as a means of stress reduction in daily life. *Psychoneuroendocrinology* 60, (October 2015), 82–90. https://doi.org/10.1016/j.psyneuen.2015.06.008

[15] Alexandra Linnemann, Jana Strahler, and Urs M. Nater. 2017. Assessing the Effects of Music Listening on Psychobiological Stress in Daily Life. *J. Vis. Exp. JoVE* 120 (February 2017), 54920. https://doi.org/10.3791/54920

[16] Osmo Mattila, Arto Korhonen, Essi Pöyry, Kaisa Hauru, Jani Holopainen, and Petri Parvinen. 2020. Restoration in a virtual reality forest environment. *Comput. Hum. Behav.* 107, (June 2020), 106295. https://doi.org/10.1016/j.chb.2020.106295

[17] Ethan A. McMahan and David Estes. 2015. The effect of contact with natural environments on positive and negative affect: A meta-analysis. *J. Posit. Psychol.* 10, 6 (November 2015), 507–519. https://doi.org/10.1080/17439760.2014.994224

[18] Alison O'Meara, Marica Cassarino, Aaron Bolger, and Annalisa Setti. 2020. Virtual Reality Nature Exposure and Test Anxiety. *Multimodal Technol. Interact.* 4, 4 (October 2020), 75. https://doi.org/10.3390/mti4040075

[19] Silvia Francesca Maria Pizzoli, Ketti Mazzocco, Stefano Triberti, Dario Monzani, Mariano Luis Alcañiz Raya, and Gabriella Pravettoni. 2019. User-Centered Virtual Reality for Promoting Relaxation: An Innovative Approach. *Front. Psychol.* 10, (March 2019). https://doi.org/10.3389/fpsyg.2019.00479

[20] Thomas G Plante, Laura Coscarelli, and Maire Ford. Does Exercising with Another Enhance the Stress-Reducing Benefits of Exercise?

[21] Florian Soyka, Markus Leyrer, Joe Smallwood, Chris Ferguson, Bernhard E. Riecke, and Betty J. Mohler. 2016. Enhancing stress management techniques using virtual reality. In *Proceedings of the ACM Symposium on Applied Perception*, July 22, 2016. ACM, Anaheim California, 85–88. https://doi.org/10.1145/2931002.2931017

[22] Borbála Tölgyesi, Ágnes Karolina Bakk, Máté Barkóczi, Balázs Buri, András Szabó, Botond Tobai, Bonita Sadie, Renáta Cserjési, Iva Georgieva, and Christian Roth. 2023. "Virtual reality nature as our next retreat?": User experience testing of a simulated natural environment in virtual reality. In *Mensch und Computer 2023*, September 03, 2023. ACM, Rapperswil Switzerland, 448–453. https://doi.org/10.1145/3603555.3608543

[23] Marieke Van Rooij, Adam Lobel, Owen Harris, Niki Smit, and Isabela Granic. 2016. DEEP: A Biofeedback Virtual Reality Game for Children At-risk for Anxiety. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, May 07, 2016. ACM, San Jose California USA, 1989–1997. https://doi.org/10.1145/2851581.2892452

[24] Chia-Pin Yu, Hsiao-Yun Lee, and Xiang-Yi Luo. 2018. The effect of virtual reality forest and urban environments on physiological and psychological responses. *Urban For. Urban Green.* 35, (October 2018), 106–114. https://doi.org/10.1016/j.ufug.2018.08.013

[25] 2023. The Relationship Between Hearing the World Around You and Improved Mental Health. *Ear Science Institute Australia*. Retrieved June 12, 2024 from https://www.earscience.org.au/2023/03/27/hearing-and-improved-mental-health/

[26] 2023. Uncanny Valley: Examples, Effects, & Theory. Retrieved June 12, 2024 from https://www.simplypsychology.org/uncanny-valley.html

[27] PLAYNE : The Meditation Game on Steam. Retrieved June 12, 2024 from https://store.steampowered.com/app/865540/PLAYNE__The_Meditation_Game/

[28] Releasing Stress Through the Power of Music | Counseling Services | University of Nevada, Reno. Retrieved June 12, 2024 from https://www.unr.edu/counseling/virtual-relaxation-room/releasing-stress-through-the-power-of-music

[29] The Cognitive Benefits of Interacting With Nature - Marc G. Berman, John Jonides, Stephen Kaplan, 2008. Retrieved June 12, 2024 from https://journals.sagepub.com/doi/10.1111/j.1467-9280.2008.02225.x

[30] Meta Quest 3: nieuwe mixed reality VR-headset - Shoppen | Meta Store | Meta Store. Retrieved June 12, 2024 from https://www.meta.com/nl/quest/quest-3/?utm_source=gg&utm_medium=ps&utm_campaign=20557143580&utm_term=meta%20quest%203&utm_content=688564931400&utm_funnel=dcap&gad_source=1&gclid=CjwKCAjw65-zBhBkEiwAjrqRMMMtunp_DmunJK1pzzYzjHLCDyxaYQthK70eCeOqpMOBgqJ_TWT3RhoCM50QAvD_BwE&gclsrc=aw.ds

[31] Fitbit Inspire 3 | Health & fitness tracker. Retrieved June 12, 2024 from https://www.fitbit.com/global/nl/products/trackers/inspire3

[32] Unreal Engine 5. Retrieved June 12, 2024 from https://www.unrealengine.com/en-US/unreal-engine-5

[33] All About Heart Rate. *www.heart.org*. Retrieved June 12, 2024 from https://www.heart.org/en/health-topics/high-blood-pressure/the-facts-about-high-blood-pressure/all-about-heart-rate-pulse

[34] Abstract Music | Definition & Meaning | M5 Music. Retrieved June 12, 2024 from

https://www.m5music.hk/en/dictionary/abstract-music/
[35] Spatial Presence - an overview | ScienceDirect Topics. Retrieved June 12, 2024 from https://www.sciencedirect.com/topics/computer-science/spatial-presence

APPENDICES

Appendix A - Interview Questions

INTERVIEW RESEARCH VR EXPERIENCE

Participant number:

Date:

Time:

Interviewer:

This research study is about the effect of the spectrum of reality on stress reduction of students. This means that we have built two different virtual experiences in different styles. One being realistic and the other abstract. In this study you will be experiencing one of the following:

- Realistic Experience
- Abstract Experience
- Mixed Experience: Meaning you will get the abstract visual with the realistic music.

The study will take around 10-15 min in total. Before we continue, we ask you to put on this Fitbit, this will measure your heart rate and oxygen levels.

We have a handful of questions we'd like you to fill in before we start the experience. After you have filled these in, we will give you the VR headset so you can experience the virtual world we have built. While finishing up, we will conduct a small interview about your experience.

Pre study questions
(Please circle or fill-in where applicable)

How much stress would you say you have experienced recently?

None	Light	Mild	Moderate	Severe

How often would you say you have experienced this stress in the past week?

Never	Rarely	Sometimes	Often	Always

How stressed would you say you are right now?

Not	Lightly	Mildly	Moderately	Severely

Debrief questions:

How did you experience this research?

How did you feel while doing the test?

How stressed would you say you are right now?

Not	Lightly	Mildly	Moderately	Severely

Did you feel any kind of (stress) relief during or after the VR environment?

IF RELAXED: What elements made you feel relaxed?

Where would you say the visual stands on the spectrum of reality?

Realistic	Semi-Realistic	Neutral	Stylized	Abstract

Do you think the visuals in the VR experience helped with relaxation?

Where would you say the audio stands on the spectrum of reality?

Realistic	Semi-Realistic	Neutral	Stylized	Abstract

Do you think the audio in the VR experience helped with relaxation?

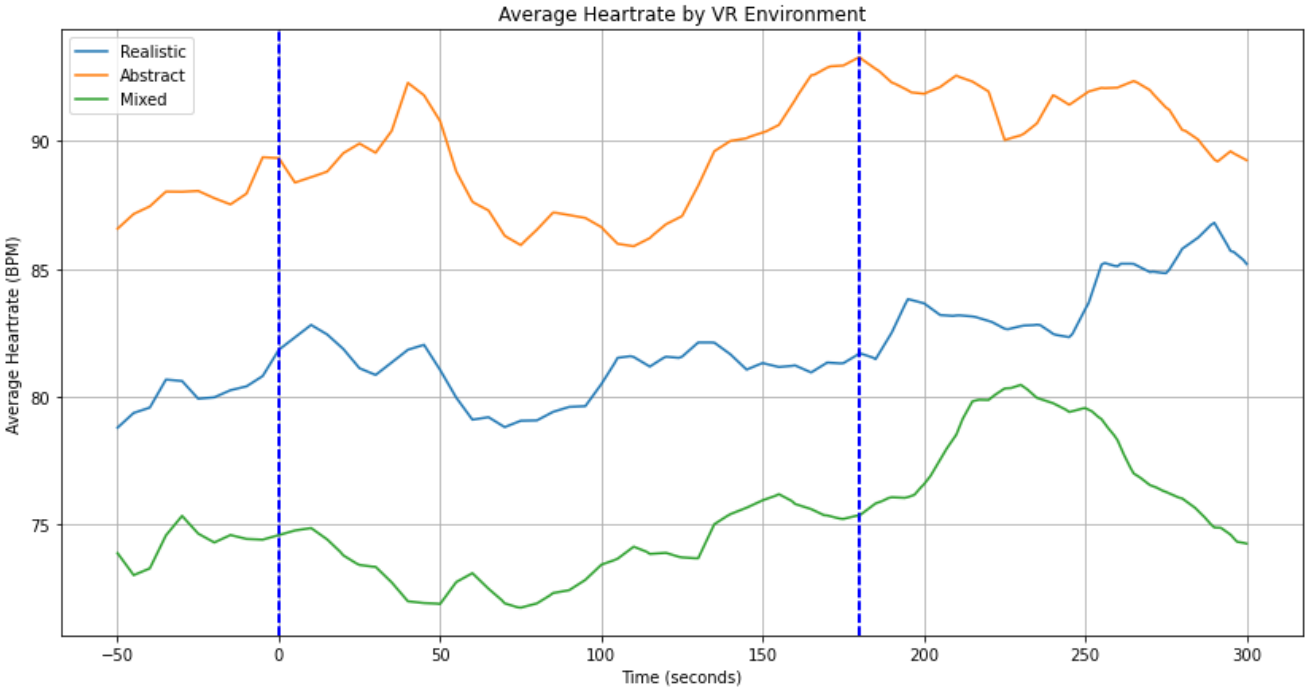
Do you want to experience the alternative VR environment?

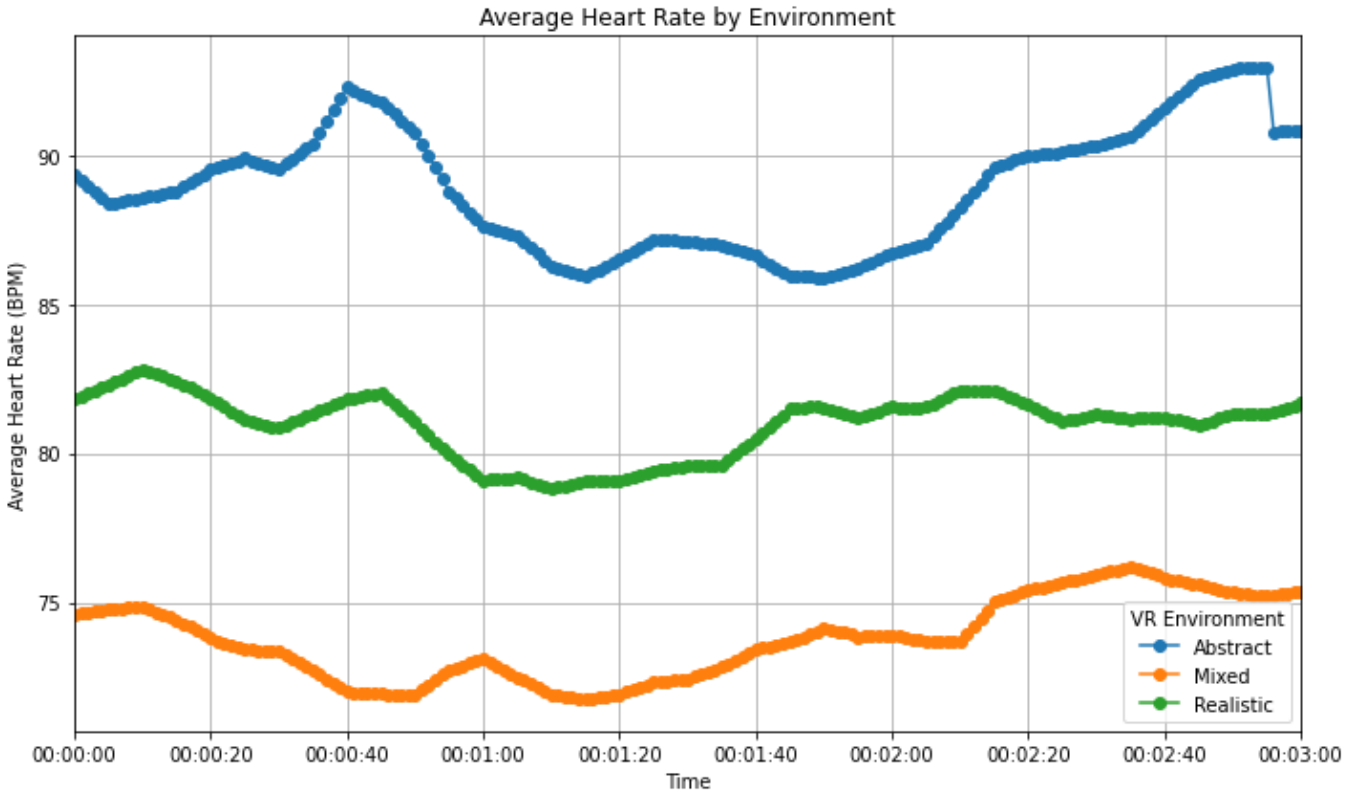
○ YES

○ NO

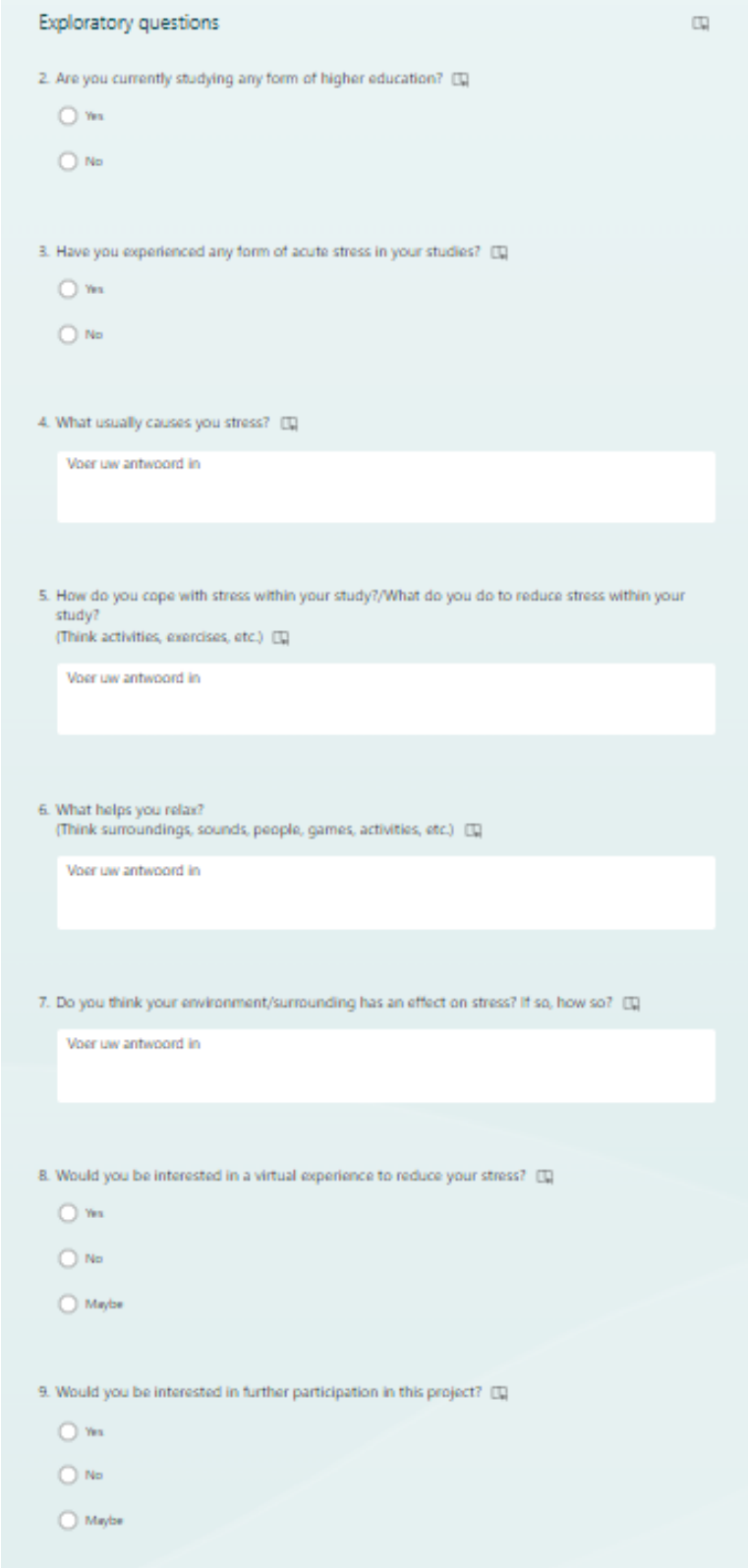
IF YES: Do you think you would prefer this other environment over the other? (What elements (Visual/Audio?))

Appendix B - Data Analysis Graphs





Appendix C - Questionnaire Questions



Exploratory questions

2. Are you currently studying any form of higher education?
- Yes
- No

3. Have you experienced any form of acute stress in your studies?
- Yes
- No

4. What usually causes you stress?

Voer uw antwoord in

5. How do you cope with stress within your study?/What do you do to reduce stress within your study?
(Think activities, exercises, etc.)

Voer uw antwoord in

6. What helps you relax?
(Think surroundings, sounds, people, games, activities, etc.)

Voer uw antwoord in

7. Do you think your environment/surrounding has an effect on stress? If so, how so?

Voer uw antwoord in

8. Would you be interested in a virtual experience to reduce your stress?
- Yes
- No
- Maybe

9. Would you be interested in further participation in this project?
- Yes
- No
- Maybe

Appendix D - Informed Consent Form

Information sheet for research project B2.2 Hyperreality Empowerment

1. Introduction

Eindhoven Technical University (TU/e invites you to take part in research project B2.2 Hyperreality Empowerment, because you responded to our initiation in a TU/e communication channel.

Joining this research project is your choice. Your participation is completely voluntary and does not pose any physical, legal or economic risks. You are not obliged to answer questions you are uncomfortable with, and you can withdraw from the research at any time without explaining why. Declining or withdrawing will not have negative impact for you.

Before you decide, please read the following information to understand what the research is about, what we expect from you and how we handle your personal data. After reading, you can sign up by completing the attached form.

If you have questions, feel free to contact the researcher via l.smit@student.tue.nl. You can also discuss this information with people you trust.

2. Purpose of the research

The purpose of this research project is to determine how the spectrum of realism affects stress reduction in virtual experiences.

The project is managed by Erik van der Spek.

During this study, you will be presented with a VR experience, aiming for stress reduction. For this, you will be asked several interview questions; some questions before the experience, and some after. During this study, your heart rate will be recorded to calculate stress levels and see how the VR experience affects your stress relief.

3. Controller in the sense of the GDPR

TU/e is in charge of handling your personal data for the research. You can contact TU/e at:

Technische Universiteit Eindhoven
De Groene Loper 3
5612 AE Eindhoven

4. What will taking part in the research project involve?

In the research project we will collect your personal data using the methods:

- Interviewing you about the experience and writing down your answers via pen and paper.
- Experiment involving smart watch and VR goggles

For your participation you will not be compensated.

5. What personal data from you do we gather and process?

We collect and process the following personal data which is necessary for the project purpose:

Category	Personal data	Purpose	[Retention period]
Physiological data	Heart rate	Analyse the results of the project and our research question, calculate stress levels	Data files (anonymised); Until end of project and any retakes Graphed/documented results in report (anonymised): 10 years (as per TU/e retention period)
Interview answers (notes)	Questions about the virtual reality experience	Analyse the experience through the user's responses	Written notes: Until end of project and any retakes Documented answers in report (anonymised): 10 years (as per TU/e retention period)
Contact details	Name, email	Contacting you for planning the interview/experiment	Until June 7th

Your data is retained only for the time period as specified in the table. Keeping your data for this period helps us to comply with scientific principles, such as producibility and verification. After this period, your personal data will be deleted or anonymized to ensure it can no longer be linked to you.

6. Stopping your participation

If you end your participation in the research we will not use your data anymore from that moment on.

For questions, ending your participation, or complaints, please contact the researcher via l.smit@student.tue.nl.

You have the right to request access, rectification, objection, erasure or adaptation of your data. Submit your request through privacy@tue.nl.

For concerns or questions about the handling of personal data e-mail the data protection officer of TU/e at dataprotectionofficer@tue.nl. You can also file a complaint with the Dutch data protection authority: the Autoriteit Persoonsgegevens.

7. Legal basis for processing your personal data

We process your personal data because it is part of the university's public task to conduct scientific research as stated in article 1.3 of the Dutch Wet Hoger onderwijs en Wetenschappelijk onderzoek. The TU/e always follows established codes of conduct for research integrity and the scientific standards.

8. Who has access to your personal data?

Access to personal data within TU/

Only authorized employees involved in the research, like students in the project group, members of the committee that keeps an eye on the safety of project, have access to your personal data, but only if necessary for their tasks. The authorized employees will keep your personal data confidential.

Access to personal data by other parties

For processing your personal data in this project, we will use the services of the following parties:

- Storage solution*: Microsoft Onedrive (Netherlands)*
- *Device: Fitbit*

With these parties TU/e has a suitable agreement in place to ensure specific obligations to protect your personal data are followed.

TU/e will process your personal data within the European Economic Area (EEA) by storing your data on a server inside the EEA.

9. How are your personal data protected?

TU/e has implemented appropriate technical and organizational measures to protect personal data. These measures include using centrally managed and verified research and storage tools, in addition to limited data access through authorization and authentication.

10. Confidentiality, storage of data and future research

The collected data will be stored on TU/e's Microsoft Onedrive.

We will make sure that any published research results will not include confidential or identifiable information about you unless you explicitly agreed to it, for example if you want your name to be mentioned in publications.

This research has been assessed and approved by the ethical committee of Eindhoven University of Technology.

***** Scroll down for the form *****

CONSENT FORM FOR PARTICIPATION BY AN ADULT

By signing this form, I confirm:

1. I have enough information about the research project from the separate information sheet. I have read it and I had the chance to ask questions, which have been answered to my satisfaction.

2. I take part in this research project voluntarily. There is no explicit or implicit pressure for me to take part in this research project and I understand I can stop my participation at any moment, without explaining why. I do not have to answer any question I do not want to answer.

3. I know my personal data will be collected and used for the research, as explained to me in the information sheet.

Furthermore, I consent to the following parts of the research project:

4. I consent to my answers being used for quotes in the research publications – without including my name.

   YES ☐ NO ☐

Name of Participant:

Signature:

Date:

Name of researcher:

Signature:

Date:

Appendix E – Role Division in the project

Project Task Division

- Questionnaire
- Conceptualization
- Everything Ethics (ERB, Informed Consent, Data Steward)
- Build Realistic Virtual Experience
- Build Abstract Virtual Experience
- Build Mixed Virtual Experience
- Prepare Fitbit for data analysis
- Create Interview
- Conducting Interviews
- Notekeeping within Interviews
- Heart rate data analysis and graph visualisation
- Realistic Experience Interview Analysis
- Abstract Experience Interview Analysis
- Mixed Experience Interview Analysis
- DemoDay Posters
- Design Presentation

Sjoerd Aendekerk

- Questionnaire
- Conceptualization
- Asset creation Abstract Virtual Experience
- Asset creation Mixed Virtual Experience
- Prepare Fitbit for data analysis
- Create Interview
- Conducting Interviews
- Heart rate data analysis and graph visualisation

Thijs

- Questionnaire
- Conceptualization
- Build Realistic Virtual Experience
- Build Mixed Virtual Experience
- Create Interview
- Conducting Interviews
- Realistic Experience Interview Analysis
- DemoDay Posters
- Design Presentations

Hai Lam Ha

- Questionnaire
- Conceptualization
- Build Abstract Virtual Experience:
- Build Mixed Virtual Experience:
- Create Interview:
- Conducting Interviews:
- Abstract Experience Interview Analysis:

Luke

- Questionnaire lead
- Conceptualisation
- Everything Ethics (ERB, Informed Consent, Data Steward)
- Create Interviews
- Notekeeping within interviews
- Mixed experience Interview Analysis

Report Task Division

- Abstract
- Introduction
- Related Works
- Methodology
- Design
- Results – Quantitative
- Results – Qualitative
- Results – Interesting Findings
- Conclusions
- Discussion
- References

Sjoerd Aendekerk

- Introduction
- Related Works
- Results – Quantitative

Thijs

- Related Works
- Results – Qualitative
- Results – Interesting Findings
- Conclusions

Hai Lam Ha

- Related Works
- Methodology
- Design
- Discussion

Luke

- Abstract
- Related Works
- References