applied sciences

MDPI

Article

Therapeutic Potential of Interactive Audiovisual 360-Degree Virtual Reality Environments for Anxiety Reduction—A Case Study with an Abstract Art Application

Ilmari Jyskä [1,*], Kaija Puura [2,3] and Markku Turunen [1]

[1] TAUCHI Research Center, Faculty of Information Technology and Communication Sciences, Tampere University, FI-33014 Tampere, Finland
[2] TamCAM Research Center, Faculty of Medicine and Health Technology, Tampere University, FI-33014 Tampere, Finland
[3] Department of Child Psychiatry, Tampere University Hospital, Central Hospital, P.O. Box 2000, FI-33521 Tampere, Finland
* Correspondence: ilmari.jyska@tuni.fi

Featured Application: Binaural Odyssey is a virtual reality relaxation application based on generative abstract animations and binaural sounds that react to the user's head movements with the aim of influencing the user's emotions.

Abstract: The increasing contrast between limited resources and growing demand in psychiatric care for anxiety disorders has caused an urgent need to find new cost-effective methods for treatment. This article studies the therapeutic potential of interactive audiovisual abstract art in a 360-degree virtual reality environment as a method for reducing anxiety and inducing relaxation. The study consists of experimental research of a virtual reality relaxation application called Binaural Odyssey. This research was conducted with 13 research participants between June and August 2021, and it uses a within-subjects design. Digital questionnaires, structured interviews, Heart Rate Variability (HRV) data, and the researcher's observations during the research situation were used to gather research data. Results of the study suggest that this method can produce positive mental health effects for the users, such as reduced anxiety and tension, as well as increased relaxation levels and mental resources. Binaural Odyssey is a promising prototype of this method, but it lacks parity regarding application contents and clear therapeutic goals and, therefore, cannot be recommended for treatment purposes. However, further development with mental health professionals could pave the way for a new functional treatment method for reducing and controlling anxiety and tension.

Keywords: user experience in virtual reality; virtual reality therapy; virtual reality art; heart rate variability; stress relief

Citation: Jyskä, I.; Puura, K.; Turunen, M. Therapeutic Potential of Interactive Audiovisual 360-Degree Virtual Reality Environments for Anxiety Reduction—A Case Study with an Abstract Art Application. *Appl. Sci.* **2022**, *12*, 9316. https://doi.org/10.3390/app12189316

Academic Editor: Dimitris Mourtzis

Received: 25 August 2022
Accepted: 14 September 2022
Published: 16 September 2022

1. Introduction

The increasing contrast between limited resources and growing demand in psychiatric care for anxiety disorders [1–3] has caused an urgent need to find new cost-effective methods for treatment. Recent studies have demonstrated positive effects of virtual reality applications in treating psychiatric disorders while highlighting the need for further research [4]. In order to address these needs, this article studies the potential of a novel virtual reality method to induce relaxation and relieve tension via a virtual reality application that generates spatial abstract animations and binaural sounds that react to the user's head movements in a 360 virtual environment.

Virtual reality technology has made significant advances in recent years, enabling the appearance of a wide variety of virtual reality applications. Lately, the technology has found its way into hospitals and therapeutic wards with various virtual rehabilitation

applications, as well as to numerous entertainment purposes—practically speaking, current virtual reality technology provides a cost-effective and immersive spatial platform that can be used to induce emotions via powerful audiovisual stimuli in various ways, which in turn can be highly beneficial in psychiatric care [5]. Virtual reality methods allow readily available and repeatable treatment, while also supporting the consistency of treatment delivery [6].

Virtual reality has been used since the 1990s in exposure therapy to experience problematic emotional triggers in a safe and controlled manner—early examples of virtual reality exposure therapy (VRET) include therapy for arachnophobia [7] and treatment for war veterans suffering from PTSD [8]. Lately, more subtle ways to affect human emotions in virtual reality have emerged, such as virtual natural environments, which aim to reduce stress and induce relaxation with digitally replicated real natural environments [9,10]. Yet there seems to remain a large amount of unexplored potential regarding virtual reality therapy in terms of methods for promoting mental health and for psychiatric care, and one interesting direction for new ideas is reactive abstract art.

Art has been with us since prehistoric times, evolving from ancient cave paintings to the modern world of art—evolving from an early form of communication to a multidisciplinary creative craft that aims to affect human emotions in various ways. Communication does exist in modern art as well, right in the heart of it, but is often used in a way that leaves room for interpretation. The definition of art itself seems to be elusive and a matter of perspective rather than some definite attributes that apply to all situations [11]. Regardless of the definition, virtual reality provides a new platform for modern art as well, providing artists an immersive 360-degree interactive audiovisual canvas. The relaxation application studied in this article, Binaural Odyssey [12], uses these artistic possibilities in an attempt to cause positive mental health effects to the users.

Although art therapy was introduced in the 1920s and has slowly gained some popularity, art is still commonly thought to exist mainly in the realm of entertainment, while therapy is connected to health care—two very different areas of expertise. In other words, art and therapy are commonly thought to serve different functions. However, in reality, art and therapy can easily co-exist in the same application; it is more a matter of definition, verified effects, user group, and purpose. This paper studies an artistic virtual reality relaxation application with the aim of investigating the potential of the method it uses for therapeutic purposes and the factors that contribute to that potential. It also aims to provide some details about the factors that contribute to the difference between virtual reality entertainment and virtual reality therapy.

The following chapters present the case studied and the methods of the study, followed by a presentation of the study results and a discussion about the implications of the study, before discussing the limitations of the study and finally reaching conclusions and recommendations.

2. Materials and Methods

2.1. Case: Binaural Odyssey

> *"See how sounds and shapes help mental health in virtual reality. The aim of Binaural Odyssey is to create and guide the user's emotions. The virtual world reacts to the eyes of the viewer and creates visual shapes from whichever direction the user looks at."* [12]

Binaural Odyssey is a relaxation application that aims to induce and guide the emotions of the user with a continuous randomized loop of audiovisual stimuli in a virtual reality environment that reacts to the head movements of the user. It creates animated visual shapes in the direction the head-mounted display is facing in a 3D 360-degree virtual environment while providing a never-ending ambient binaural audio background for the experience. The application makes use of different colors and shapes, as demonstrated in Figure 1, and, according to its developers, the aim of the application is both to relax and energize the user [13].

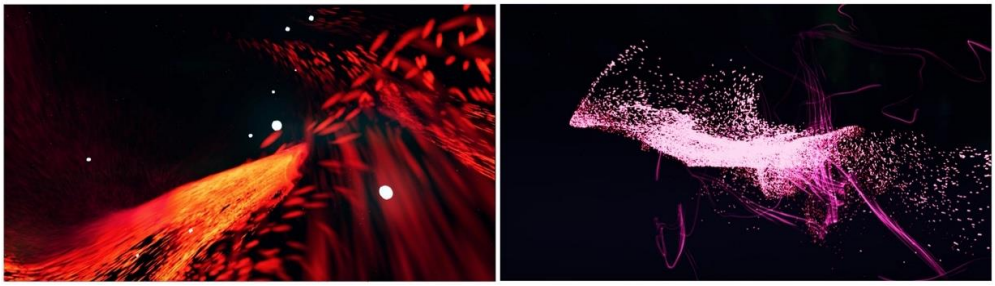

Figure 1. Two screenshots from the Binaural Odyssey application.

Binaural Odyssey is used with a head-mounted virtual reality display that is connected to a computer running the software. It is designed to be used with headphones due to the spatial nature of the sounds in the application, and either internal or external headphones can be used. Due to the nature of the application, there is no clear structure to the experience—it starts when the application is started and goes on until the user removes the headset used for the experience.

Due to lessons learned during pilot testing of the research protocol, it was decided that in this study the participants would use the application for a period of five minutes, as it was estimated that users could grow bored with the application if the timeframe was longer.

Binaural Odyssey development was conducted by Yle Sandbox, which promotes innovation and experimenting culture in Finland's national public broadcasting company, Yle [14], in collaboration with RagingRam Oy. In practice, the development was done mainly by an interactive media professional with over 20 years of working experience in media. It should be noted that no mental health professionals were involved in any part of the design process. The application is available for free download from the Steam online store [12]. Evaluation of the effects of Binaural Odyssey was initially suggested in the Human Optimized XR (HumOR) research project [15].

2.2. Research Methods

The experimental user experience research of Binaural Odyssey used a within-subjects design and was conducted between 23 June–13 August 2021 in a research laboratory of Tampere University with 14 Finnish adult research participants, who used Binaural Odyssey in a controlled setting. However, due to technical problems during the experiment, one research participant was excluded from this study, resulting in 13 research participants. These participants were acquired from both personal and professional contacts of the research group, which resulted in a diverse but relatively academic user group. The study was conducted in the Finnish language.

In order to get necessary data for evaluating the therapeutic potential, we gathered both subjective and objective data about the user experience of the participants. The subjective data consisted of interviews and digital questionnaires, and Heart Rate Variability (HRV) data was collected during the study to get objective insight into the functioning of the autonomous nervous system (ANS) of the participants.

Previous studies have found higher HRV to be associated with higher emotional well-being [16,17]. In this study, we focused on SDNN, RMSSD, and Baevsky's stress index (SI) mean values. SDNN and RMSSD values relate to the activity of the parasympathetic nervous system [18], giving insights into the relaxation level of the subject, while Stress Index (SI) is a geometric measure of HRV that reflects cardiovascular system stress [19]. High SI values indicate reduced HRV and an activated sympathetic nervous system, whereas a reduced SI value would indicate the desired effect for a therapeutic relaxation application.

During the experiment, the participants were first briefed about the research and their rights as a research participant, before being asked to wear a Polar H10 heart rate monitor chest strap. An Android smartphone with the Elite HRV application was used to collect HRV data from the Polar H10 during the experiment.

The research situation was divided into three phases: Pre-intervention, VR-intervention, and Post-intervention. Research participants were in a sitting posture in each phase, which had a minimum length of five minutes to ensure proper HRV data samples for analysis.

During pre-intervention, the participants were interviewed about their background information, with a focus on prior experience regarding virtual reality and their relaxation skills. Participants also filled in several digital questionnaires—a perceived stress scale PSS-10 to measure their initial stress level and a variation of SUXES [20] with a Likert scale (1–7) to evaluate their expectations regarding *Q1 Quick Adaption to VR*, *Q2 Immersivity of VR*, *Q3 Focus to task* (relaxation), *Q4 Sensory conformity*, *Q5 Visual experience*, and *Q6 Auditory experience* aspects of the experience with Binaural Odyssey. Finally, participants filled out a Current State Of Mind (CSOM) [21] questionnaire to evaluate current subjective feelings regarding their levels of *Anxiety*, *Tension*, *Relaxation*, and *Resources* with a Likert scale (0–10). This phase also served as a baseline HRV measurement.

In VR intervention, the participants used Binaural Odyssey with an HTC Vive head-mounted display and Audio-Technica ATH-M40 X headphones for a duration of five minutes. The participants were sitting on a rotating chair and encouraged to fully experience the 360-degree nature of the virtual reality experience. The researcher ensured a smooth setup for the experience and observed the situation during the intervention. The HRV measurement from this phase was later compared to both the baseline measurement and post-intervention measurement. In Figure 2, a research participant can be seen with the research setup in the VR intervention phase.

Figure 2. Test participant using Binaural Odyssey during the experimental research. The computer on the right side of the picture was used for digital questionnaires.

After five minutes had passed, the researcher helped participants to remove the headset and headphones, and the participants proceeded to fill out more digital questionnaires as the post-intervention phase started—CSOM to evaluate possible changes to subjective feelings of the participant, SUXES to evaluate their experience and compare that data to the expectations, and a UEQ+ questionnaire [22] regarding the *Attractiveness*, *Usefulness*, and *Value* of the experience. When ready with the questionnaires, the participant answered

to a structured interview conducted by the researcher vocally. The following questions were asked:

1. *Did you experience nausea while trying Binaural Odyssey?*
   a. If needed: *Describe in more detail?*
2. *Did you experience technical problems while trying Binaural Odyssey?*
   b. If needed: *Describe in more detail?*
3. *What grade would you give to the realization of the Binaural Odyssey? (0–10)*
   c. *Do you want to comment on the rating?*
4. *Is there anything else you want to say about the Binaural Odyssey?*
5. *Would you be willing to use the Binaural Odyssey again?*
6. *Would you be willing to use an enhanced version of Binaural Odyssey?*
7. *What improvements would you like to see in the Binaural Odyssey?*

After at least five minutes had passed and all relevant questions were asked, the researcher ended the HRV recording and the experiment was declared to be over, which was followed by a more informal debriefing session with answers to any possible questions the participants had.

After the experiment, all research data was analyzed by the researcher in a time period from autumn 2021 to spring 2022. Kubios HRV Premium [23] was used to analyze the HRV data from the experiment, and SPSS [24] was used to calculate the statistical data.

2.3. Measures

The Perceived Stress Scale 10 (PSS-10) is a 10-item questionnaire designed to evaluate the self-reported amount of stress in the participants by assessing thoughts and feelings in the previous month. Each question is scored from 0 (never) to 4 (very often) with a total possible score range of 0 to 40. A higher score indicates a high level of stress.

SUXES is a user experience evaluation method designed to compare the self-reported expectations and experiences of the participants regarding an application. Expectations are measured before the user experiment, while experiences are measured after using the application. Data are collected with a set of questions that are identical in both measurements and use a 7-point Likert scale for measurement. In this article, we use a simplified variation that measures expectations with one answer (expectation) with values ranging from 0 (strongly disagree) to 6 (strongly agree), whereas original SUXES used a two-point answer to determine the range of expectations (from acceptable to desired).

The Current State of Mind questionnaire (CSOM) is a set of questions regarding the subjective emotional states of the user, asked both prior to and after exposure to the experience studied. It uses 11-point Likert scales (0–10) to collect data, which are used to analyze changes to self-reported emotions between these two points of time. Value 0 indicates that the subject does not experience the emotion in question at all in that moment, while value 10 indicates extremely strong emotional experience regarding that emotion.

User Experience Questionnaire+ (UEQ+) is a modular user experience questionnaire, which is used to measure the user experience of interactive products. It includes a total of 20 sets of questions, all of which measure different UX aspects of a product studied. Each question set contains four questions regarding the topic and one optional question regarding the importance of this aspect to the user. All questions use a 7-point Likert scales to collect data. This study uses question sets regarding aspects of *Attractiveness*, *Efficiency*, and *Value*, and does not use the optional question regarding importance.

3. Results

Data from 13 participants were included in the results—except for HRV data, where data of one participant were excluded from the research due to data quality issues detected by Kubios HRV Premium. The mean age of the 13 participants was 41.0 ($\pm$12.0 SD) and the gender division was seven females and six males. The mean PSS-10 result was 11.9

(±6.2 SD), which indicates low stress levels and that the sample population was somewhat less stressed than the general population [25,26]. Six participants had some prior experience regarding VR head-mounted devices, while seven participants had not experienced any VR application. Only one participant expressed having extensive VR experience. Seven participants had experience with meditation or yoga, while six did not. No participant reported issues regarding technical problems or nausea.

3.1. Questionnaires

CSOM questionnaires produced statistically significant positive results, which can be seen in Figure 3. All research participants reported a decrease in anxiety, unless it was already 0 in the first CSOM measurement, in which case the value stayed at zero. Nine participants reported a decrease in tension, while one participant reported a slight increase. Three participants reported unchanged values, out of which two had the value 0 in both measurements. Regarding their level of relaxation, ten participants reported an increase, while one participant reported a decrease, and two participants did not change their evaluation regarding that emotion. Finally, eight participants reported an increase in their mental resources and one participant reported a slight decrease, while four participants reported an unchanged level of mental resources.

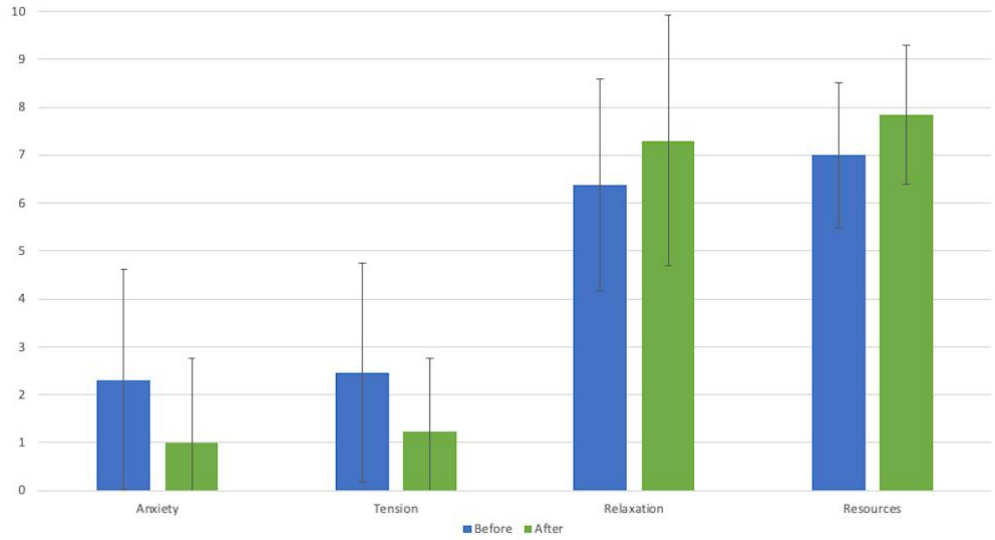

Figure 3. CSOM results. Bars indicate the means of subjective evaluations of experienced mental states before and after the VR intervention.

Two dependent variables *t*-tests between pre- and post-intervention conditions revealed statistically very significant results regarding *Anxiety* $t(11) = -3.9$, $p < 0.01$, with a mean change of −1.31, and *Tension* $t(11) = -3.4$, $p < 0.01$, with a mean change of −1.23. Furthermore, statistically significant results were found regarding *Relaxation* $t(11) = 2.8$, $p < 0.05$, with a mean change of +0.92, and *Resources* $t(11) = 2.9$, $p < 0.05$, with a mean change of +0.95.

These results indicate that subjective feelings of anxiety and tension decreased, while subjective levels of relaxation and resources increased. In more practical terms, CSOM results indicate a potential for therapeutic use. However, it should be noted that both PSS-10 and CSOM results indicate that the participants represent a user group that is already in a relatively good mental state before using the application, whereas in therapeutic use the target users are likely to be significantly more anxious and stressed out, which limits the applicability of these results.

SUXES questionnaire results indicated a good general virtual reality experience which met the expectations of the participants across all questions and even surpassed some of them, as can be seen from Figure 4. When comparing the expectations to experiences, two dependent variables *t*-tests between pre- and post-intervention conditions of SUXES

questionnaires were conducted. Questions *Q1 Adaption to VR, t(11) = 1.8, p = 0.10*; *Q3 Focus to task, t(11) = −0.18, p = 0.86*; *Q5 Visual experience, t(11) = 0.61, p = 0.55*; and *Q6 Auditory experience, t(11) = 0.66, p = 0.45*, did not reveal statistically significant results with $p < 0.05$. However, in *Q2 Immersion of VR, t(11) = 2.7, p < 0.05*, the change was statistically significant with a mean value of +0.92, and in *Q4 Sensory conformity, t(11) = 2.2, p < 0.05*, the change was statistically significant with a mean value of +1.00.

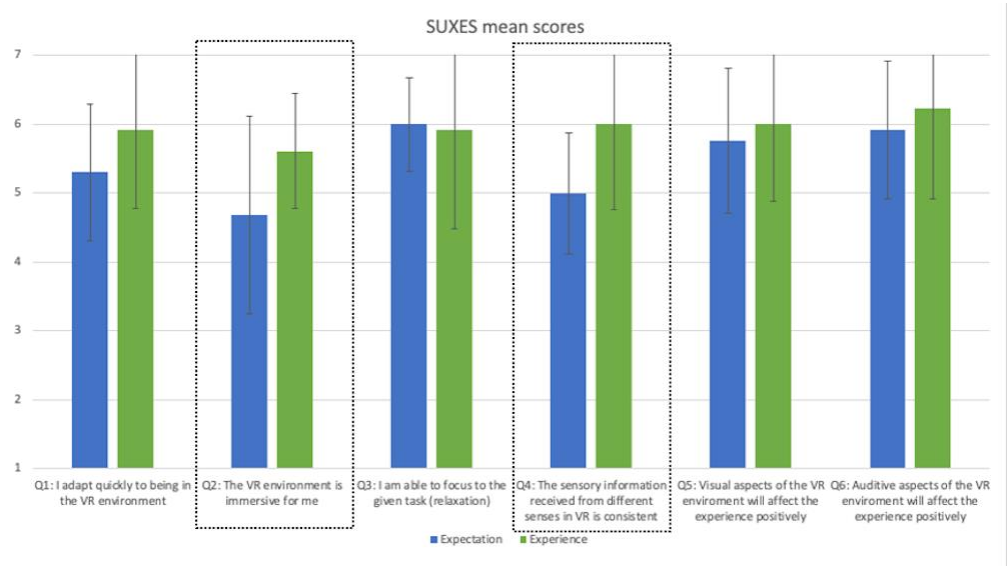

Figure 4. SUXES results. Bars indicate the means of subjective evaluations of expectations and post-intervention experiences regarding the application used. In Q2 and Q4, the change was statistically significant.

In practice, this means that participants seem to have been positively surprised about the experienced immersion and sensory conformity while using the application, which is a desired outcome for most virtual reality applications—especially so for one that uses abstract animations and spatial soundscapes as its main functionality.

Finally, UEQ+ results indicated relatively good user experience across all used scales. UEQ scale results can have a value between −3.00 to +3.00. *Attractiveness* had the highest mean score of +1.96 (±0.88 SD), while the *Usefulness* scale received a mean score of +1.56 (±0.89 SD). The third scale, *Value*, received a mean score of +1.65 (±0.92 SD).

To summarize the questionnaire results, all findings point towards a positive user experience and positive mental health effects. However, it should be noted that most of the participants had only little to no prior experience regarding virtual reality applications, and especially SUXES and UEQ+ results could be different from those of more experienced user groups. In other words, the technology used was novel and exciting for most of the participants, which most likely had an effect on the results.

3.2. Interviews

Post-intervention interviews revealed a generally positive attitude towards the experience. The mean grade to the experience given by the participants was 8.27 (±1.07 SD) out of 10, and 11 participants stated willingness to try the Binaural Odyssey again at some point, while all the participants stated willingness to try an improved version of the application in the future.

> *"Grade: 7.5—The soundscape worked very well for relaxation, but the visual landscape was both relaxing and activating. For pure relaxation, it would have worked better without the visual side. As such, it served more as a virtual art experience."* (Participant, 34 years)

Six participants expressed a clear positive attitude towards the experience, while the rest were more neutral in their responses. No participant expressed indications of a clearly negative experience. Over half of the participants (8) expressed views in various wording that the application felt a bit unpolished. Most commonly this was used in reference to the structure of the experience—a common view was that the participant would have wanted a more relaxing experience, as activating elements of the experience disturbed the relaxation process.

> *"Grade: 9—I didn't give full points because the pixels were a bit out of focus and the white line jumped to my face uncomfortably. It disturbed the concentration."* (Participant, 53 years)

The most commented element in the application was the appearance of *a fast white line*, which can be seen in Figure 5, and which was basically a 3D white line that draws itself around the user with a quick pace, being the only element in the application that moves as fast and comes as close to the user. It received only negative comments, mostly about disturbing the experience.

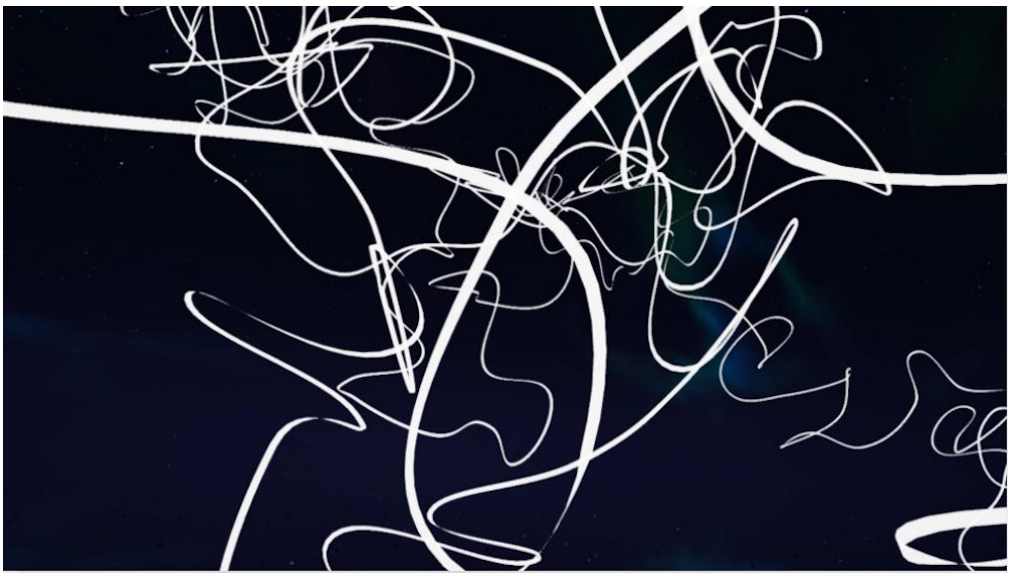

Figure 5. Screenshot from Binaural Odyssey application, featuring an element labeled fast white line in this article.

To summarize the interviews, participants seemed to have enjoyed the experience in general, while some were pleasantly surprised about the novelty of the experience. The sound design of the application received only positive comments. However, the application felt a bit like a work in progress for most of the participants—the main improvement suggestions included improved structure of the experience, more thoughtful use of colors in the animations, and focusing on either relaxing or activating elements instead of trying to achieve both. Several participants mentioned that the product worked better as an art experience, rather than a relaxation application, indicating a need for a more goal-directed approach when using this method for stress reduction purposes.

3.3. HRV Data

HRV data were analyzed from only 12 participants due to data quality issues regarding one participant. SDNN values between pre- and post-intervention conditions increased for all 12 participants, while RMSSD values of 10 participants increased and results from 2 participants stated a decrease. SI values decreased for 11 participants, while the data from one participant stated a slight increase.

Statistical analysis of HR, SDNN, RMSSD, and SI values in three different conditions were conducted with repeated measures ANOVAs. Mean values of these variables can be seen in Table 1. Regarding SDNN, RMSSD, and SI values, the mean scores between conditions were statistically significantly different. SDNN *[F(2,22) = 21.888, p < 0.0005]*, RMSSD *[F(2,22) = 10.086, p = 0.001]*, SI *[F(1.243,13.675) = 14.077, p = 0.001]*. Regarding HR, no statistically significant difference between conditions was found. HR *[F(2,22) = 5.114, p = 0.015]*. However, we can observe a slight decrease in HR mean values between the baseline and intervention measures. This could be explained by the fact that participants had recently arrived at the research location prior to the baseline measurement, and for some, the heart rate could be still slightly elevated from the preparations for the study, while in intervention and post-intervention measurements, the participant had been sitting down for a longer time due to the design of the research. In addition, any possible initial nervousness regarding the research participation in general is likely to be most visible in the baseline measurement.

Table 1. Mean values of HR, SDNN, RMSSD, and Stress Index (SI) from 12 participants in three five-minute measurements, recorded during baseline measurement, while using Binaural Odyssey, and after the virtual reality intervention.

HRV Variable	Baseline Mean Value (SD)	VR Intervention Mean Value (SD)	Post-Intervention Mean Value (SD)
HR	74.83 (±9.49)	72.33 (±8.46)	72.67 (±8.57)
SDNN	33.88 (±11.51)	26.58 (±9.15)	40.34 (±11.53)
RMSSD	26.12 (±10.09)	23.33 (±9.03)	29.50 (±9.54)
SI	13.21 (±3.34)	16.39 (±6.14)	11.16 (±3.25)

Paired samples *t*-tests were conducted to determine the effect of VR intervention on HRV regarding values of SDNN, RMSSD, and Stress Index (SI). When comparing the values between baseline and post-intervention conditions, the results of the paired sample *t*-tests showed that the mean differences of SDNN *[Mean difference = −6.47 (±5.06 SD)]*, RMSSD *[Mean difference = −3.38 (±5.03 SD)]*, and Stress Index *[Mean difference= +2.05 (±1.66 SD)]* were all statistically significant at the 0.05 level of significance *[SDNN t(11) = −4.43, p = 0.001; RMSSD t(11) = −2.33, p = 0.040; SI t(11) = 4.26, p = 0.001]*. This indicates increased activity of the parasympathetic nervous system and decreased activity of the sympathetic nervous system, which can imply reduced stress levels and increased feeling of relaxation.

HRV data analysis reveals that, while using the application, the SDNN, RMSSD, and SI values all indicate increased sympathetic nervous system activity in comparison to both the baseline and post-intervention measurements, which implies a stressful experience. Furthermore, the HRV data indicates an increased level of relaxation and decreased level of stress after the experiment in comparison to the baseline values. In other words, while the experience itself seems to have been intensive, it produced a relaxing effect.

3.4. Correlations

In order to gain insight into the therapeutic qualities of the method studied, a two-tailed Pearson correlation coefficient was computed to assess the linear relationship between PSS-10 results, which indicate the stress level of the participant, and the following variables from the research data: grade given, differences of CSOM values before and after the intervention, and differences of HRV data variables before and after the intervention.

Regarding PSS-10 and the grade the participant gave, there was an indication to relatively strong negative correlation between the two variables, *r(11) = −0.549, p = 0.052*, which was on the verge of being statistically significant at *p < 0.05*. However, neither CSOM values nor HRV data revealed significant correlation between PSS-10 and the measured effect, with *AnxietyChange r(11) = −0.172, p = 0.575*; *TensionChange r(11) = −0.364, p = 0.221*; *RelaxationChange r(11) = 0.294, p = 0.330*; *ResourcesChange r(11) = 0.252, p = 0.407*; *SDNNChange r(10) = 0.331, p = 0.293*; *RMSSDChange r(10) = 0.274, p = 0.390*; and *SIChange r(10) = −0.402,*

$p = 0.195$. In other words, while it seems like more stressed participants tended to give lower grades to the application, no correlation between initial stress level and measured subjective or objective therapeutic effects of the experience could be found. This offers some encouragement for the idea that the method studied could have potential in therapeutic use, while higher stress levels could theoretically explain a more negative mindset when reviewing the experience, thus resulting in a lower grade.

4. Discussion

According to the research data, the user experience regarding this method is generally positive and the application studied caused positive mental health effects to the study population, which consisted of a diverse but relatively balanced participant group that did not have much prior experience with virtual reality applications. The immersiveness and sensory conformity of the experience was higher than the participants expected, which implies a technically solid design where visual and audio elements are well balanced. However, this can be considered a somewhat excepted result from a participant group that is inexperienced with the technology.

The use of novel technologies such as virtual reality applications for the first time is likely to be a positive experience on its own, and that causes limitations to the interpretations of these research results. Furthermore, according to the PSS-10 results and supported by CSOM results, it can be stated that the stress levels of the participants were lower than in the general population, which is especially noteworthy as this research was conducted during stressful times of the Covid-19 pandemic. In other words, these results apply only to this study population, which was inexperienced in VR and had relatively good mental health, and the results could be somewhat different with other study populations.

Both objective and subjective measurements used in this study point towards positive mental health effects. According to CSOM results, the subjective feelings of anxiety and tension decreased and feelings of relaxation and resources increased among the research participants after using Binaural Odyssey. Likewise, HRV results state increases in SDNN and RMSSD levels and a decrease in Stress Index, implying a more relaxed state of mind after exposure to the method studied. This all indicates potential for therapeutic use. It seems like the methods the application uses have potential to produce similar relaxing effects as virtual natural environments [9,10,21]. However, several research participants stated that they would have preferred either only relaxing content, or only activating content, and felt that the current mixture of the two lessens the therapeutic qualities of the application studied.

The study results indeed point to the direction that the user experience of Binaural Odyssey is both an art experience and a therapeutic experience—but leaning towards art due to unstructured presentation and mixture of both relaxing and activating content. In order to harvest the full potential of this method for therapeutic use, more thoughtful use of colors and shapes, a more structured approach to the design of the experience, and development done in collaboration with mental health professionals would be recommended. In addition, elements that can disturb the experience, such as the fast white line in Binaural Odyssey, should be avoided.

When considering which factors made the fast white line disturbing, it can be noted that it moved much faster than any of the other elements in the application, and it also seemed to come closer to the user in the 3D space than the other elements. In addition, it did not work well together with the auditive experience, as the soundtrack did not include similarly fast-paced elements and sound design did not seem to be directly in synchrony with the animations, being rather a smooth spatial ambient background with only thematic connections to the visual presentation. Hence, the fast white line could have been disturbing to the experience due to being thematically misplaced. However, for activating content such a solution could be justifiable, but as the application had mostly relaxing content and the participants were told to try to relax with the application, this element seemed to only disturb the process.

For artistic experience, the mixture of soothing and surprising elements is a valid choice. However, when art is used in a therapeutic way, it usually involves the process of creating the art as a key element of the session. Studies have shown that sessions of art making can reduce experienced anxiety significantly [27,28], although the amount of studies regarding the subject remains limited. The application used in this study is, however, a relatively passive experience for the user. The user does interact with the application with head movements, as most of the animations appear in the direction the head-mounted display is facing, but the user has no control over the contents or timing of the animations or soundscapes. Therefore, it should not be considered as a tool for making art. For art therapy purposes, more interaction and user control over the contents of the experience would plausibly increase the therapeutic quality of the product, especially regarding user groups that are in need of activating psychiatric treatment for anxiety.

The sound design of Binaural Odyssey is simplistic, consisting only of the background sound ambiance which consisted of different binaural ambient sound loops played out in a seemingly random order. However, the participants were generally more pleased with the sounds than the visual side of the application, as sounds gathered several positive remarks from the participants and no negative notions. We estimate that the spatial nature of the soundscape is an important factor regarding the experience in this method, as it encourages the user to look around, and increases the feeling of being in a 3D abstract virtual space, due to providing a novel audio experience that reacts to the head movements similarly to real environments.

The initial stress level of the participants seemed to correlate negatively to the grade given to the experience, but no correlation to measured effects of the intervention could be found. This indicates that the stress level of the participant has no significant effect to the therapeutic qualities of this method, although the evidence can be considered weak and more research with a larger study sample and with more variety in PSS-10 results would be required to confirm this finding.

To gain further insight, we compared the effects of the method studied regarding HRV to similar studies that involved therapeutic relaxation applications. Lukic et al. [29] used a similar research setup to study physiological responses and user feedback on two breathing training smartphone applications by comparing the HRV data regarding baseline and intervention measurements. Unfortunately, no post-intervention data was collected in this study, but Lukic et al. found that measures of SDNN and RMSSD increased very significantly during the interventions. This is no surprise, as deep breathing is one of the main methods to reduce stress and increase relaxation. Similarly, Trivedi and Saboo [30] concluded in their study that the use of Himalayan singing bowls significantly and relatively linearly increased RMSSD and decreased SI values during a 20 min relaxation session when compared to starting values, but their research as well did not include post-intervention measures. However, it is noteworthy that the method Binaural Odyssey uses seems to cause the opposite effect during the intervention, and the elevated SDNN and RMSSD values appear only after the intervention.

Interestingly, Ahmaniemi et al. [31] stated in their study of virtual reality applications and stress recovery at the workplace that HRV parameters did not show a significant difference between pre-intervention, intervention, and post-intervention conditions, even though other post-intervention measures indicated increased relaxation. One reason for this might have been the variable chosen to analyze HRV, which was the LF/HF ratio.

Limitations

These research results are only indicative, as no definite conclusions can be formed due to the limited amount of research participants. The statistical power of the results remains low. Furthermore, research participants were quite inexperienced regarding VR solutions, which might have affected the results—experiencing virtual reality for the first time can be a positive experience in itself. Participants also reported low levels of stress. It needs to be noted that different sample populations could produce different results—meaning that

the effects of the method studied might be significantly different for users with high stress levels or extended experience regarding VR applications.

Due to the lack of a control group in our study, any possible effect caused by experiencing VR with a head-mounted display cannot be differentiated from the effects caused by Binaural Odyssey. Although this does not affect the results regarding the general applicability of VR solutions for psychiatric care, more research with a control group would be needed in order to confirm that the positive effects found in this study are caused by the method studied in this article.

In addition, this research provides no data on how long the positive effects last, or how repeated use would affect the results and user experience.

To summarize, the results of this research should not be used to justify therapeutic use of the methods studied in this article for psychiatric treatment, as more research with more stressed and anxious user populations would be required to verify the suitability of this method for therapeutic care.

5. Conclusions

Binaural Odyssey is an example of a method that uses interaction based on generative spatial abstract audiovisual art in a virtual space that reacts to user head movements to induce positive mental health effects, and the results imply that this method can reduce anxiety and tension of the users, as well as to cause increases in relaxation levels and mental resources. However, the user group that produced these results was small and consisted of users with relatively low stress levels and low previous experience regarding virtual reality applications, which is likely to have an impact to the results.

As a therapeutic application, Binaural Odyssey is still unpolished and not recommended for therapeutic treatment due to a lack of parity regarding application contents and clear therapeutic goals. However, further development with mental health professionals could pave the way for a new functional treatment method for reducing and controlling anxiety and tension.

The method of using reactive abstract animations accompanied by soothing binaural sounds in therapeutic virtual reality applications can be evaluated to be promising, although the elements should be in parity with therapeutic goals. These design considerations include different operating modes for relaxing and activating content, as well as goal-oriented design regarding the structure of the experience, regarding all audiovisual elements, and regarding the amount and methods of interaction with the user. Special attention should be paid to the integrity of the experience regarding the use of colors and audiovisual parity.

Binaural Odyssey can be evaluated to be essentially a piece of art. The main factors that contribute to this are the lack of structure regarding the experience and the randomized mixture of relaxing and activating content regarding visual output—both of which are artistic choices that are likely to reduce the therapeutic potential of the application. However, the methods the application uses are promising for therapeutic purposes, and further research is recommended.

Author Contributions: Conceptualization, I.J., K.P. and M.T.; methodology, I.J., K.P. and M.T.; validation, I.J., K.P. and M.T.; formal analysis, I.J. and K.P.; investigation, I.J.; data curation, I.J.; writing—original draft preparation, I.J.; writing—review and editing, I.J., K.P. and M.T.; visualization, I.J.; supervision, K.P. and M.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Ethical review and approval were waived for this study due to all subjects being adult volunteers who gave their informed consent to participate in this non-invasive study; thus, according to Finnish legislation, no ethical review was needed.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Summary of the data presented in this study is contained within the article. Full dataset not available due to ethical and privacy issues.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. COVID-19 Practitioner Survey. Available online: https://www.apa.org/pubs/reports/practitioner/covid-19-2021 (accessed on 24 August 2022).
2. Demand for Mental Health Treatment Continues to Increase, Say Psychologists. Available online: https://www.apa.org/news/press/releases/2021/10/mental-health-treatment-demand (accessed on 24 August 2022).
3. Pauliina Happo Lapsen Elämä on Monimutkaistunut ja Psykiatrista Hoitoa Haetaan Enemmän Kuin Koskaan—Lue Viiden Kipukohdan Lista Siitä, Mikä Hoidossa Mättää. Available online: https://yle.fi/uutiset/3-10527451 (accessed on 24 August 2022).
4. Cieślik, B.; Mazurek, J.; Rutkowski, S.; Kiper, P.; Turolla, A.; Szczepańska-Gieracha, J. Virtual reality in psychiatric disorders: A systematic review of reviews. *Complement. Ther. Med.* **2020**, *52*, 102480. [CrossRef] [PubMed]
5. Geraets, C.N.W.; van der Stouwe, E.C.D.; Pot-Kolder, R.; Veling, W. Advances in immersive virtual reality interventions for mental disorders: A new reality? *Curr. Opin. Psychol.* **2021**, *41*, 40–45. [CrossRef]
6. Freeman, D.; Reeve, S.; Robinson, A.; Ehlers, A.; Clark, D.; Spanlang, B.; Slater, M. Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychol. Med.* **2017**, *47*, 2393–2400. [CrossRef] [PubMed]
7. Rothbaum, B.; Hodges, L.; Kooper, R. Virtual reality exposure therapy. *J. Psychother. Pract. Res.* **1997**, *6*, 219–226. [PubMed]
8. Rothbaum, B.O.; Hodges, L.; Alarcon, R.; Ready, D.; Shahar, F.; Graap, K.; Pair, J.; Hebert, P.; Gotz, D.; Wills, B.; et al. Virtual reality exposure therapy for PTSD Vietnam Veterans: A case study. *J. Trauma. Stress* **1999**, *12*, 263–271. [CrossRef] [PubMed]
9. Ojala, A.; Neuvonen, M.; Leinikka, M.; Huotilainen, M.; Yli-Viikari, A.; Tyrväinen, L. *Virtuaaliluontoympäristöt työhyvinvoinnin voimavarana: Virtunature-tutkimushankkeen loppuraportti*; Luonnonvarakeskus: Helsinki, Finland, 2019; ISBN 978-952-326-799-2.
10. Mattila, O.; Korhonen, A.; Pöyry, E.; Hauru, K.; Holopainen, J.; Parvinen, P. Restoration in a Virtual Reality Forest Environment. *Comput. Hum. Behav.* **2020**, *107*, 106295. [CrossRef]
11. Adajian, T. The Definition of Art. In *The Stanford Encyclopedia of Philosophy*; Zalta, E.N., Ed.; Metaphysics Research Lab, Stanford University: Stanford, CA, USA, 2022.
12. Binaural Odyssey on Steam. Available online: https://store.steampowered.com/app/1421100/Binaural_Odyssey/ (accessed on 24 August 2022).
13. Seija Aunila See How Sounds and Shapes Help Mental Health in Virtual Reality. Available online: https://yle.fi/aihe/artikkeli/2020/10/15/see-how-sounds-and-shapes-help-mental-health-in-virtual-reality (accessed on 24 August 2022).
14. Santonen Heidi Yle Sandbox is a Concept that Promotes Innovation and Experimenting Culture at Yle. Available online: https://yle.fi/aihe/artikkeli/2020/04/08/yle-sandbox-is-a-concept-that-promotes-innovation-and-experimenting-culture-at (accessed on 24 August 2022).
15. Human Optimized XR—Open Source Standard for XR. Available online: https://humanoptimizedxr.org/wp/ (accessed on 24 August 2022).
16. Beauchaine, T.P.; Thayer, J.F. Heart rate variability as a transdiagnostic biomarker of psychopathology. *Int. J. Psychophysiol. Off. J. Int. Organ. Psychophysiol.* **2015**, *98*, 338–350. [CrossRef] [PubMed]
17. Kemp, A.; Quintana, D. The Relationship Between Mental and Physical Health: Insights from the Study of Heart Rate Variability. *Int. J. Psychophysiol. Off. J. Int. Organ. Psychophysiol.* **2013**, *89*, 288–296. [CrossRef] [PubMed]
18. Shaffer, F.; Ginsberg, J.P. An Overview of Heart Rate Variability Metrics and Norms. *Front. Public Health* **2017**, *5*, 258. [CrossRef] [PubMed]
19. Baevsky, R.; Chernikova, A. Heart rate variability analysis: Physiological foundations and main methods. *Cardiometry* **2017**, *10*, 66–76. [CrossRef]
20. Turunen, M.; Hakulinen, J.; Melto, A.; Heimonen, T.; Laivo, T.; Hella, J. SUXES—User experience evaluation method for spoken and multimodal interaction. *Interspeech 2009* **2009**, 2567–2570. [CrossRef]
21. Jyskä, I. Effects of Virtual Natural Environment and Meditative Guidance to Stress Reduction in Therapeutic Applications. Master's Thesis, Tampere University, Tampere, Finland, 2020.
22. Schrepp, M.; Thomaschewski, J. Handbook for the Modular Extension of the User Experience Questionnaire. 2019. Available online: https://www.researchgate.net/publication/334030490 (accessed on 24 August 2022).
23. Tarvainen, M.P.; Niskanen, J.-P.; Lipponen, J.A.; Ranta-Aho, P.O.; Karjalainen, P.A. Kubios HRV—Heart rate variability analysis software. *Comput. Methods Programs Biomed.* **2014**, *113*, 210–220. [CrossRef] [PubMed]
24. *IBM SPSS Statistics for Windows*; Version 27.0; IBM Corp.: Armonk, NY, USA, 2020.
25. Cohen, S.; Kamarck, T.; Mermelstein, R. A global measure of perceived stress. *J. Health Soc. Behav.* **1983**, *24*, 385–396. [CrossRef] [PubMed]
26. *Measuring Stress: A Guide for Health and Social Scientists*; Cohen, S.; Kessler, R.C.; Gordon, L.U. (Eds.) Oxford University Press: New York, NY, USA, 1997; pp. xii, 236, ISBN 978-0-19-508641-6.

27. Sandmire, D.; Gorham, S.; Rankin, N.; Grimm, D. The Influence of Art Making on Anxiety: A Pilot Study. *Art Ther.* **2012**, *29*, 68–73. [CrossRef]
28. Abbing, A.; Baars, E.W.; de Sonneville, L.; Ponstein, A.S.; Swaab, H. The Effectiveness of Art Therapy for Anxiety in Adult Women: A Randomized Controlled Trial. *Front. Psychol.* **2019**, *10*, 1203. [CrossRef] [PubMed]
29. Lukic, Y.X.; Shih, C.-H.; Reguera, A.H.; Cotti, A.; Fleisch, E.; Kowatsch, T. Physiological Responses and User Feedback on a Gameful Breathing Training App: Within-Subject Experiment. *JMIR Serious Games* **2021**, *9*, e22802. [CrossRef] [PubMed]
30. Trivedi, G.Y.; Saboo, B. A Comparative Study of the Impact of Himalayan Singing Bowls and Supine Silence on Stress Index and Heart Rate Variability. *J. Behav. Ther. Ment. Health* **2019**, *2*, 40–50. [CrossRef]
31. Ahmaniemi, T.; Lindholm, H.; Muller, K.; Taipalus, T. Virtual Reality Experience as a Stress Recovery Solution in Workplace. In Proceedings of the 2017 IEEE Life Sciences Conference (LSC), Sydney, Australia, 13–15 December 2017; pp. 206–209.