Comparing the effects of VR and 2D screen nature meditation on STAI anxiety levels

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Abstract- Improvements in VR (Virtual Reality) have made mental health improvement tools such as meditation more varied and practically available. In particular, the emulation of a natural environment such as a forest may be useful as a tool to calm down the anxiety levels of individuals. This paper explores the effect on anxiety of a forest environment coupled with a simple sight meditation and forest music through two different emulation approaches. Firstly, a 360-degree Oculus Quest 2 VR forest image. Secondly, a 14-inch 2D screen simply displaying a picture of the same forest. The approaches were made to be as similar as possible by controlling all other variables such as time spent meditating and sounds heard. Such a comparison is motivated by how it can be hard to find nature close by to modern working spaces or homes. These two approaches act as possible practical solutions in their infancy to help bring more time in natural environments to our lives, to hopefully improve our wellbeing as a result. This study acts as a reference point for more advanced techniques. Examples of other more advanced VR meditation solutions exist, but they often require equipment (such as EEG or BCI [1] [2] that are currently not in wide availability. Having used the STAI Y-1 anxiety questionnaire to measure anxiety, there was no significant evidence of an improvement in the alleviation of anxiety for either approach at the 5% or 10% significance level. Some explanations and next steps are then explored. Specifically, there are obvious technical but also more nuanced improvements to the VR setup that may improve the results. Also, there is some commentary on the type of meditation (sight) and its place in VR and mental health in the future.

I. Introduction

It is well known that the presence of natural elements (green spaces) has a positive effect on the wellbeing of humans [3][4]. Indeed, natural elements and sunlight exposure relate positively to job satisfaction and organisational commitment, and negatively to depressed mood and anxiety [5]. This work aims to examine whether emulating elements of nature, i.e., the view of a natural forest environment through a 360-degree image on an Oculus Quest 2 or an image through a standard PC monitor, in conjunction with a short sight meditation and forest music, can decrease anxiety recorded on the STAI Y-1 questionnaire.

This study is inspired by the pandemic forcing many individuals to work from home. The interactions that tend to result from working from home tend to be from usual desktop/PC environments and as a result are static. Such static interactions, combined with the other social distances measures, seem to have put a significant burden on the mental health of especially younger people (particularly suicidal thoughts) [6]. Therefore, other methods that allow working from home in a more dynamic and natural way may be an important necessity. VR could very well be such a method as it's 360-degree field of view allow a freedom of movement that is arguably much more natural. It has the possibility to help provide some of what the outside world offers but at home from many work [7], exercise [8], and meditation [9] applications.

Coincidentally, individuals with physical disabilities that impair movement and those bedridden could also benefit greatly. Also, those in prisons or any other circumstances that prevent free movement. Furthermore, this study is also motivated by the advent of VR technology exponentially becoming more affordable, ubiquitous, and practical for mental health improvement applications. Specifically, the ability for VR technology to allow unprecedented escapism from the workplace environment may make VR an impressive tool for deep rest within the physical confines of an office. It is expected that emulating a natural space using VR technology will be much more immersive than emulating it using a simple 2D monitor because it provides much more freedom of movement which is arguably more natural. This study aims to explore as a result whether this makes VR technology better at decreasing stress and anxiety levels.

II. Related Works

The psychological effects of viewing a forest through virtual reality and through a 2D screen have been investigated throughout the literature, but few articles exist that directly compare the VR approach to the 2D screen approach. It was not possible to find a study specifically comparing VR and 2D for forest sight meditations. Thus, in the following we are exploring related research on 2D forest/nature images, VR forest/nature, and VR versus 2D for guided meditation, separately. s

A. 2D Forest/Nature Images

There are studies investigating the psychological effects from methods similar to this study's 2D screen approach. One such study includes simulating a natural environment by viewing a sideshow of pictures of it. This is then compared to relaxing within a real natural environment. The results suggest that while both environments facilitated about equal efficiency in stress reduction, the natural environment also increased the energy of its participants more [10]. This implies that while the simulation of nature is a good approach for stress reduction, there also is still room to grow and improve from the 2D approach. Consequently, one motivation for this work is the possibility of virtual reality technology being the natural successor from the 2D approach due to its vastly increased immersion factor. Such an immersion factor may be a good direction to grow the 2D simulation approach to close the gap between it and real nature. It is worth noting that while stress reduction could be found with a 2D screen with Kjellgren and Buhrkall's approach but not in this works', their relaxation time lasted 30 minutes instead of the 5-minute approach that this study took.

An investigation perspective more orientated towards neuroscience explored the difference in frontal cortex activation, whilst viewing projected images of foliage plants compared to actual foliage plants. It concluded that the frontal cortex responded differently, even though the subjective emotional response (comfort, relaxation) was similar [11]. Moreover, the participants recorded the real plants elicited a much more natural feeling than the images. This study is noteworthy because it implies that there is a disconnect in subjective feedback and brain activity in the simple 2D versus real life comparison. As a result, much care must go into the complications of how exactly to accurately measure and improve mental health states when technology is involved. This problem is even further exacerbated with VR technology involved and implies that the approach taken in our study to measure anxiety via questionnaire alone may not be sufficient by itself to provide evidence of stress reduction.

B. VR Forest/Nature

One such study [12] investigating immersion in virtual reality nature settings includes participants performing a stress-induction task and then immersion in one of two VR settings for 10 minutes. Comparing against a control group that viewed a slideshow of abstract organic art paintings in VR, it found that participants who underwent an active exploration of a VR forest exhibited decreased stress. This study first and foremost does well to confirm that the anxiety decreasing effects are coming from the emulation of nature in VR, and not the usage of VR itself. It also confirms that emulating nature is a good approach for stress reduction in VR. Lastly, note that the exploration of the nature environment in this study was active, allowing free movement in a photo-realistic forest.

Such an active exploration of the forest is different to the fixed camera position that was our approach. Their approach employed no meditation techniques, just free roaming. Most meditation techniques (including simple sight meditation) tend to be conducted from a stationary fixed position. Accordingly, our study attempted to adhere to this. However, the study cited may indicate that better results could come from more active VR experiences. One possible application could be to combine their active forest exploration with movement orientated meditation techniques such as mindful walking [13].

Browning et al [14] compared the effects of outdoor nature exposure against 360-degree VR nature video. They found that both can increase physiological arousal and benefit positive mood levels (in control with an indoor setting without nature), but only outdoor nature exposure increased positive mood levels. Such results imply a limitation in the current VR approach to substitute for real nature, but also validates the need for such a substitute for those lacking nature due to circumstance. Therefore, it is important to note that the aim of this field of research is not necessarily to provide experiences more beneficial than nature immediately, but instead to provide better substitutions for it for the individuals who need them.

There are a number more studies that found positive results for human exposure in VR natural environments. For instance, a study found that viewing 360-degree videos of forest or waterfall was able to decrease fatigue and depression in comparison to urban environments [15]. This validated our motivation to try and use VR as a method get more time in natural environments. Another study's [16] results indicated that VR natural scenes showed improved relaxation qualities over a control scene depicting an empty (no people/plants/animals) indoor classroom.

C. VR vs 2D For Guided Meditation

A useful comparison between a 360-degree video guided VR meditation against a standard 2D laptop meditation has been undergone [17]. This study had young university students (n = 82) undergo both approaches to find that the VR meditations were associated with less distractibility from the process of breathing, lower fatigue, and a greater experience of relaxation. In contrast to our paper, their meditation technique was different. Although they were also five-minutes long, they were guided: it had scripted meditation instructions being played during the meditation itself. This such approach may be better for inexperienced meditators and is further discussed later within this paper, bearing in mind that it appeared to be more effective.

III. Hypotheses

There are three main hypotheses that this paper investigates.

Hypothesis 1: That a 5-minute sight meditation emulating nature using VR will decrease the anxiety of participants.

Although there may be some discomfort for participants using the headset, i.e., the physical discomforts such as the weight on their head and perhaps some eye-ache, we expect that the calming effect from meditation will outdo these effects and decrease the anxiety of participants regardless.

Hypothesis 2: That a 5-minute sight meditation emulating nature using a simple 2D PC screen will decrease the anxiety of participants.

We expect that meditation is likely going to decrease the anxiety of participants regardless of whether the emulation quality of a 2D-screen being low. Because the calming effect from meditation will be significant.

Hypothesis 3: That the meditation utilizing VR will decrease the anxiety of participants more than the meditation utilising a 2D PC screen.

This hypothesis intends to explore if VR technology is indeed better at providing an immersive natural environment than a simple 2D-screen that would allow it to (potentially significantly) lower the anxiety of participants. We expect VR to outperform the 2D environment due to increased immersion. For instance, it allows for 360 degrees interaction covering the whole field of vision of the user, as well as allowing head movement for the user to look around the scene naturally and thus focus on potentially more naturally on objects of interest.

IV. Methodologies

The methodology for both the VR and 2D Screen scenarios are kept very similar to allow for a fair comparison. At the start of the experiment, the participant is sat down and given a STAI-Y questionnaire to fill in. State-Trait Anxiety Inventory (STAI) [18] was created by Spielberger C.D and Gorsuch R.L. It is a questionnaire detailed to measure trait and state anxiety. Form Y, the most popular version, was used in this study. It has 20 questions dedicated for assessing state anxiety. State anxiety (S-Anxiety) is the temporary psychological state that the respondent feels at the moment at hand. This was appropriately used at the start and end of meditations to access the psychological effects that resulted due to it. Trait anxiety, a measurement of the more general and long-term features of anxiety that a participant feels, was inappropriate for this study as we were interested in the short-term effects of meditation on anxiety. However, measurements of trait anxiety may prove to be useful data for future studies to explore the longitudinal effects of different meditation/nature emulation approaches on an individual's anxiety and mental health. The range of STAI scores for each subtest is 20–80, the higher score indicating greater anxiety. A cut point of 39–40 has been suggested to detect clinically significant symptoms (which imply clinical diagnosis of anxiety for an individual) for the S-Anxiety scale [19].

Prior to being given a STAI questionnaire, the researcher comments to the participant that their inputs will not be looked at for a week to come. This is to try and avoid the participants feeling pressured into answering a certain way due to the researcher's presence, which may skew the results. Next, a pre-prepared sight meditation script is handed out (see Appendix), and they are given ample time to read and digest its instructions. Then they are handed some earphones playing some forest music – to go with the forest theme - adjusted to be at a comfortable volume. The presence of forest music is to complement the forest scenery shown and so aid the immersion factor and emulation quality. Finally, they use an Oculus Quest 2 to meditate for five minutes, and then are retested with another STAI Y-1 questionnaire. A day after at the same time, the same process is undergone but instead of an Oculus Quest 2 they meditate with the 2D PC screen approach.


Figure 1. The forest meditation image used for both VR and 2D meditations.

The sample size of this experiment is n=5. Six were invited while five accepted, broken down into 2 males and 3 females. The age range was 20-22. All participants lacked prior experience with meditation and virtual reality and were all undergraduate students reading at Durham University. Convenience sampling was implemented, and a small sample of young participants invited, due to the coronavirus restrictions making surveying other age ranges, or many individuals, within an enclosed indoor environment unfeasible. It is worth noting that the qualitative input from the participants has value irrespective of the sample size because the experience of inexperienced meditators tends to be universal and uniform, and so applicable to a larger population. Coincidentally, inexperienced meditators were sampled because such an approach to aiding mental health should not rely on meditation experience or else it's practicality of being implemented in office or home environments to beginners would be called into question. The experiments took place within the period of the first two weeks of June 2021. After the experiments, a link to a questionnaire (see appendix) was given to the participants, to fill out in their own time. The participants were informed how their data will be used. That no personal information will be stored, only their nameless anxiety scores that will be deleted after being processed. They have also been informed that they have the right to remove their data if they wish.

A. VR Headset Setup

A Insta360 ONEX camera was used in a forest location close to Durham University's science site to produce the 360-degree image used to emulate the nature environment. This image was exported from an INSP file (a proprietary file format used for Insta360 cameras) to a JPG using Insta360 Studio 2021 to a resolution of 8192x4096 pixels. This was necessary as an INSP file cannot be natively opened by an Oculus Quest 2. Insta360 Studio 2021 is freely provided software by Insta360 that allows conversion from their INSP file type to other formats, specifically aimed for 360-degree images. A resolution of 8192x4096 resolution was used, as this is the maximum resolution that the video decoder in the Quest 2 can support [20]. The highest resolution was chosen so that the participants can view as many details as possible of the scenery, which is important for sight meditation. This image was then sideloaded onto the Oculus Quest 2 using SideQuestVR and opened using the standard TV app preinstalled onto the headset. SideQuestVR [21] was used as it is a popular, simple and freely available software that allows file manipulation and installations of the Quest 2 via PC or phone. The view of this image is what the participants meditated with.

B. 2D PC Screen Setup

In this case, the same forest image used in the VR case is utilised to keep the two environments as similar as possible. This was opened in Fullscreen on a HP Pavilion Laptop 14. The maximum screen resolution is 1920x1080 pixels and screen size 14 inches. Similarly to case A, the view of this image is what the participants meditated with.

Laptops are practical to use for meditations due to their portability (to move to a quieter environment). The 14-inch screen size is reflective of the standard screen size that meditations could take place with (because standard laptop screen sizes do not vary an extreme amount).

The comparison of 1920x1080 pixels in the 2D setup with the 8192x4096 pixels in the VR setup is valid despite the immense difference in total pixels. This is because virtual reality headsets simply have lenses that are much higher resolution than standard 2D screens. This study used a standard VR headset lens against a standard laptop screen, and the resolution difference simply follows.

C. Forest/Nature Music

In both cases some royalty free non-copyright nature sounds were played at a comfortable level for the participants. This music can be found on YouTube [22]. This ensured further similarity between the two setups, with music and image being the control variables, not directly of interest to the experiment.

V. Results And Discussion

VR TEST	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Average
Before	51	40	31	31	22	35
After	47	30	24	24	23	29.6
Decrease	4	10	7	7	-1	5.4

Table 1. The STAI anxiety scores for each participant before and after the VR sight meditation.

2D TEST	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Average
Before	30	57	40	28	25	36
After	25	46	37	24	21	30.6
Decrease	5	11	3	4	4	5.4

Table 2. The STAI anxiety scores for each participant before and after the 2D sight meditation.

For the VR set, there was no significant decrease in anxiety scores at the 5% or 10% significance level for a one tailed test, $t(8) = 0.80895$ $p = .220968$, despite the fact that after meditation, the participants ($M = 35.00$, $SD = 10.98$) had a decreased average anxiety ($M = 29.60$, $SD = 10.11$). The (non-significant) decrease in the average anxiety is 5.40.

For the 2D set, there was also no significant decrease in anxiety scores at the 5% or 10% significance level for a one tailed test, $t(8) = 0.72058$ $p = .245843$, despite the fact that after the meditation, the participants ($M = 36.00$, $SD = 13.02$) had a decreased average anxiety ($M = 30.6$, $SD = 10.55$). The (non-significant) decrease in the average anxiety is thus also, coincidentally, exactly 5.40.

Therefore, neither the VR nor 2D meditation setup have evidence to suggest that they provide a significant decrease in anxiety, thus **hypotheses 1 and 2 do not hold for our dataset**.
Moreover, **hypothesis 3**, that the meditation utilising VR will decrease the anxiety of participants more than the meditation utilising a 2D PC screen, **does not hold**, as neither approaches can even be proven to decrease anxiety in the first place.

VI. Improvements and Next Steps

There are detriments to both the VR and 2D approaches that could have held them back from achieving significant supporting evidence. The first and biggest detrimental factor might be time spent meditating. For instance, this study used short and practical 5-minute meditation, while other studies such as Kjellgren and Buhrkall's [10], used a much longer 30 minutes. Perhaps a longer meditation time, such as 10 minutes, would obtain significant evidence for both or an approach. There are more factors at play however, as (especially for beginner meditators) a decrease in anxiety scores might not necessary scale linearly with time spend meditating. In the VR case this may occur due to an increasing discomfort wearing a heavy device at a lower than comfortable resolution. In the 2D case this may come from disinterest in the picture as a stimulus after a longer period and so wandering thoughts for the participant. In either case (in general meditation), it is possible to lose concentration over time and so more time spent meditating may not linearly decrease anxiety. Another important related factor is the meditation and VR experience of the participants. This is because more experienced meditators could likely sustain longer meditations. Also, as exposure to VR increases, the initial discomfort from wearing a headset may decrease. Hence, a longitudinal study tracking individuals over time as their experience in meditation and VR increases may be a good approach. More research must be done regarding optimal time spend meditating using VR and 2D approaches that also account for the experience of the participant.

For both approaches, their abilities to emulate nature are limited. For instance, in the VR approach, the Oculus Quest 2 headset has an uncomfortable weight applied to the user's head. Even more so, the 360-degree image itself was too low resolution and low field of view to feel real, and specifically this may have made meditating on the details of objects within it troublesome. This was likely rather detrimental, as the meditation technique employed (see appendix) focused on sight. Furthermore, some participants commented that the height at which the image was taken (a small distance from the floor) felt unnatural, so a natural improvement would be to use an image that more closely matches the user's height.

Unsurprisingly, simply improving the technical aspects of the VR headset, i.e., the weight, resolution, and field of view, could dramatically improve the quality of meditations done using it. This stemmed from participants commenting on it being uncomfortable to wear, and hard to focus directly on details. One participant in particular commented that they thought it was not comfortable enough to meditate with. Another commented that the 2D picture quality was much better. Potentially, some more impressive improvements

could be made to improve immersion. For instance, animals such as birds flying around could improve realism, as well as dynamic light application that matches the brightness of the scene to the brightness outside (based on time and location).

In the 2D approach, the small size of the PC screen compared to a humans' full field of view was a large drawback. The simple fact that the screen did not cover all a participants' field of view would break the immersion dramatically. A participants commented in response to particular problems they found meditating with the 2D environment that "If you're trying to go for an effect where you feel like you're there, then the 2D environment doesn't work for that". Another commented that the lack of immersion made them feel 'in the same room, the same space as where they were feeling anxiety', that the VR setup was better at providing immersion and escapism to leave the anxiety inducing space. The small screen size hindered the ability for the 2D approach to emulate a natural environment, and perhaps this was a factor that resulted in the non-significant decreases in anxiety.

A larger 2D screen would cover more of the participants field of view, but it is simply financially impractical for most individuals at home or at work to have quiet access for meditation to a big enough screen to significantly improve this problem. Additionally, intrinsically, a 2D image may always feel flat and therefore unlifelike. Therefore, a VR approach may be more functional at providing better immersion to result in decreased anxiety levels.

Another possible explanation regarding both approaches' inability to produce significant evidence has to do with the meditation skill of the meditator. The methodology of this study, to give the participant a meditation script, then take it away when they start to perform the meditation, may have been a poor design choice. This is because inexperienced meditators (such as the participants surveyed in this study) lack the meditation skill to guide themselves through calming down and remaining concentrated throughout the meditation. Like any skill, being able to relax and concentrate in meditation can be practiced and improved over time. As a beginner, an approach that is more suitable may then be a more 'guided' meditation, where there are audio cues directing the listener as to what to focus on. This was the approach of Waller et al [17] and it appeared to provide better results. However, a common sentiment between experienced meditators is that guidance can be a hindrance to their practice, so some care must be taken to understand what type of meditation is best for an individual given their experience level.

The type of meditation employed in this study (mindful sight) was done intentionally, in order to access the ability of VR meditation in the simplest use case. Such an approach is useful as a reference point to other techniques, as a comparison to know that such a simple form of meditation is not currently very effective. Other techniques have been shown to provide convincing evidence of improving mental health. For example, using an active forest exploration [12] or a guided meditation [17]. Thus, the largest limitation of the VR approach stopping it from achieving significant results may be the meditation type itself.

The place of meditation in the future of VR may be to provide a robust personalised experience for each individual user. Using up and coming EEG technology [23], integrated eye tracking, and machine learning, it may be possible for VR meditation software to customise an experience suited for a certain individual using all the data coming from this emerging technology. One such application could use biofeedback [24], that is the utilisation of real-time input from the user, such as their heart rate and EEG waves, to create a forest that has birds and other small animals and sounds that slowly decrease in activity as the meditator calms down. The amount of immersion in such an implementation due to user interaction with the environment (that also does not break meditation concentration) may provide novel improvements in decreasing stress and anxiety.

VII. Conclusion

By experimentation, this study tested the effect that a simple forest image virtual reality sight meditation has on STAI anxiety scores in comparison to a simple 2D forest screen sight meditation. The motivation behind such a comparison is stated in **hypothesis 3**, that the meditation utilising VR will decrease the anxiety of participants more than the meditation utilising a 2D PC screen. This hypothesis is founded on the idea that an increase in immersion from VR technology would result in a larger decrease of anxiety due to a higher quality of emulation of natural environments compared to a 2D screen. However, the findings for both VR and 2D meditation approaches did not provide significant evidence of a decrease in STAI anxiety scores at the 5% or 10% significance level. Hence, **hypothesis 3** is not supported by the empirically found evidence in this study.

Contributing factors to the insignificant decrease in STAI anxiety scores for both approaches are then given and discussed. Namely the length of meditation being only 5-minutes may have been a significantly detrimental factor as other studies such as Kjellgren and Buhrkall's [10] used a 30-minute-long session to achieve significant results. It is discussed however that a decrease in anxiety scores does not necessary scale linearly with an increased meditation time. Another significant factor may be the inexperience of the participants' in meditation. A more 'guided' meditation rather than a script may have been much more suitable for beginners. For the VR setup, there is an initial discomfort from wearing a headset that participants commented on. This discomfort may lower with more experience with VR. For the 2D setup, a vast lack of immersion from a small 14-inch screen may have distracted participants. Further

research must be done investigating these factors and more because of the immense potential that VR technology may have to aid mental health.

As the quality of VR technology increases exponentially, a simple baseline study such as this one is useful for reference as a comparison with the ability of more advanced future techniques utilising high potential emerging features such as EEG technology [23], neuroadaptive feedback [25], and eye tracking. For both approaches, the type of meditation (mindful sight) may have simply been ineffective (by design, it was meant to be the simplest possible) and better approaches providing better evidence already exist such as guided meditations [17].

APPENDIX

Below you will find a copy of the meditation script given to participants. This script was custom created for this study by the primary author, who is experienced in meditation, to be as simple as possible for beginner meditators.

Mediation Script

Please read some instructions below. Maybe you would like to read them multiple times.

- Firstly, get into a comfortable position where you will be okay to slowly move your head. Straighten your back.
- Slowly move your eyes around the scenario. Carefully noting the textures, colours, shapes and details of the objects around you.
- If you get distracted, refocus on noting the textures, colours, shapes and details of the objects around you.

This meditation will last five minutes. The music will stop when it is over.

Questionnaire Questions:

1. "Were there any particular problems you found when meditating with the VR environment?"
2. "Were there any particular things you liked when meditating with the VR environment?"
3. "Were there any particular problems you found when meditating with the 2D environment?"
4. "Were there any particular things you liked when meditating with the 2D environment?"
5. "Any comments on the length of the meditation?"
6. "The average decrease of anxiety for VR versus 2D approach was found in our study to be the same. Why do you think that is?
7. "Was there anything you felt was missing from the meditation?"
8. "Would you like/dislike a voice guiding you through the meditation?"
9. "Any other comments?"

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