Towards Attention-based Design of Mental Health Interventions in Virtual Reality

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Abstract. Virtual reality (VR) mental health therapy has been studied extensively, and some of the resulting interventions are already used in clinical practice. However, high-quality VR systems are still relatively expensive. There are some indications that a cheaper, low-quality VR system produces different effects in its users, though studies remain scarce. We theorize that the effectiveness of a VR intervention is determined partly by how well it directs attention towards or away from the users real body. We therefore propose a study comparing how image-quality and biofeedback during a breathing task affect anxiety levels. We hypothesize that high image quality distracts from the task, making the intervention less effective. Conversely, placing biofeedback in the virtual environment could direct attention back to the users body, increasing effectiveness. Initial results suggest individual differences in how attention is managed. A full-scale study could inform a more structured, attention-based design approach towards creating VR interventions.

Keywords: attention, anxiety, virtual reality, biofeedback, image-quality, mental health

1 Introduction

1.1 Virtual Reality and Mental Health

Over the last couple of decades, entertainment based health interventions have been studied extensively and some are already successfully used in clinical practice [1, 2]. Virtual Reality (VR) has been used as a technology and medium for these purposes. Targeted VR experiences can be effective treatment methods for individuals suffering from a range of mental health issues, suggesting that VR has huge potential within this field [3]. For example, virtual reality can quickly transport the user out of a stressful situation and into a personalized experience made to induce positive emotions [4].

Immersive virtual reality, where the user is viewing the virtual world through a head mounted display, can induce a strong sense of presence - the feeling of actually entering the computer generated world [5]. Such immersive VR has been shown to enhance the control over ones emotional response to stressful or difficult situations [6]. It has also been effectively used as exposure therapy for a range of phobia's, performing on par with real life exposure therapy in some instances [7].

VR can be used as a diagnostic tool, as treatment and as resilience training [8]. For example, virtual scenes depicting nature provide more relaxation than control scenes [9], suggesting that VR might provide the advantageous mental health effects of nature to people living in environments where it is not readily available, such as in submarines. In terms of therapy retention, VR breathing exercises are not only preferred over standard breathing techniques by patients, they are also rated as more fun and more likely to be used at home [4].

1.2 Cost and Quality

However, although the cost associated with VR has fallen dramatically in the past couple of decades, even commercially available immersive VR systems are still relatively expensive, making them inaccessible for everyday use [10]. Conventional mental health treatments rely on the affected individual's interaction with a social support group or therapist. Giving these individuals the opportunity to experience VR treatment at home gives them freedom and autonomy [11]. This makes the accessibility of the VR systems an important factor in producing these health interventions.

The accessibility of a VR system is mostly connected to its price. But before the use of cheaper systems is encouraged, we need to know whether these systems differ in their performance from their more expensive counterparts, and in what way. Research on the difference between higher and lower quality VR Head Mounted Displays (HMD's) is unfortunately scarce. Hoffman et al. [12] showed that, when using VR experiences as a form of pain relief, there was more reduction of pain reported in the higher quality HMD group than in the lower quality one. However, other studies show that that high fidelity isn't always superior to lower fidelity [13]. Instead, it can be dependent on the type of task.

As VR technology is advancing rapidly, recent studies make use of cheaper VR systems more often than before, often showing that there is big potential in developing smart-phone based VR health applications [10, 14]. However, the mechanisms behind what does and does not work in these different kinds of VR systems are still unclear.

1.3 Attention

The direction of attention is one mechanism that seems to strongly influence the effectiveness of the VR intervention. We theorize that different types of virtual reality interventions have different goals as to the direction of the attention of the user. For instance, in pain relief the goal is to distract the user from their own body and the pain it is experiencing [15]. In anxiety-reducing breathing tasks, the goal is to have the user focus on their own body and adjust their breathing accordingly. To accomplish this, distractions from outside must be limited [5]. However, if distractions from outside the virtual world must be limited to allow the user to focus on their own body, one could argue that the virtual environment itself can not be too complex or interesting, as it would also start to distract the user in a similar way.

There are multiple ways of reducing feelings of anxiety and stress, one of which is through deep, diaphragmatic, slow breathing techniques [16]. The regular practice of breathing exercises decreases sympathetic and increases parasympathetic activity in the body, improves cardiovascular and respiratory functions, decreases the effect of stress and overall improves physical and mental health [17]. It can however be hard to sustain ones attention during the exercises [18], and the techniques can be challenging for novices [1]. It would therefore be beneficial to create an experience in which the individual could focus their attention to the exercise at hand, without being distracted by any auditory or visual stimuli, preferably an experience that they would enjoy spending time in [2, 19].

The creation of an interesting and engaging VR experience that is nonetheless not too distracting is a problem that has been approached several times through the addition of biofeedback [20, 18]. A study by Zafar et al. [21] suggests that enhancing games with biofeedback makes them more effective than traditional stress self-regulation therapies, and that these games can even train breathing control in a stressful setting. In the 'DEEP' VR experience, breathing is monitored and users are shown a visualization of their own breathing, situated in the virtual environment. This feedback results in reduced anxiety levels and an increase in deep breathing skill acquisition [22].

1.4 Experimental Paradigm

Redirecting the users attention away from the real body and unto a complex, high-quality virtual environment might be useful in pain relief, but is likely not ideal for acquiring deep breathing techniques and reducing anxiety. In these cases, a low-quality VR environment might suffice or even work better. However, adding biofeedback visualizations to the virtual environment might bring the attention back to the body, regardless of how engaging the virtual world itself is. We therefore propose to study both the image-quality and the presence of biofeedback in the context of a virtual breathing exercise to reduce anxiety.

We hypothesize that a higher quality VR environment with biofeedback visualizations will results in the highest reduction of anxiety levels, followed by a lower quality VR with biofeedback. We expect the high-quality VR experience to draw more of the users attention, which is then directed towards their breathing via the biofeedback. We hypothesize that both non-biofeedback conditions will perform poorly, with the higher quality VR being the worst. We expect that the high quality virtual environment would distract the user more, making them less focused on their body and breathing and thus reducing the effects of the intervention.

By studying the mechanisms behind the different effects of image-quality and the presence of biofeedback, we hope to gain more knowledge on how to design future VR health care applications and develop the basis of design practices that can make them more accessible.

2 Methods

12 participants (5 female, 7 male) were recruited on the campus of Tilburg University. For this initial exploratory pilot, participants were not selected specifically for anxiety disorders.

There are four conditions: high quality VR with biofeedback, high quality VR without biofeedback, low quality VR with biofeedback and low quality VR without biofeedback. Each participant is assigned to two conditions; either high quality VR with and without biofeedback or low quality VR with and without biofeedback, making this study a mixed 2x2 design with the image-quality as the between subjects variable and the presence of biofeedback as the within-subject variable. The order of the conditions is randomized and counterbalanced over the participants.

2.1 Materials

Anxiety Questionnaires Level of anxiousness is measured with two different kinds of questionnaires. At the beginning of the experiment the participant are asked to fill in the Trait Anxiety Inventory, with items such as I am content; I am a steady person. [23]. The results of this questionnaire are used as a general anxiety baseline.

State anxiety is measured with the use of Subjective Units of Discomfort Scale, or SUDS [24]. The SUDS is a one-item 11-point Likert-type scale in which the participant is asked On a scale from 0 being absolutely calm and 10 being the worst anxiety you could ever feel, how do you rate yourself at this moment?. The participants rate their anxiety levels vocally three times per condition: once before entering the virtual experience, once during, and once after. We also use the delta of before-after as a measurement.

Anxiety Induction In between the two conditions we lower the induced relaxation to avoid carry-over from the first condition into the second. To achieve this we use the Velten Mood Induction Procedure - the participants read and try to imagine a number of negatively loaded sentences for one minute [25].

Diaphragmatic Breathing Rate As an objective measure, the diaphragmatic breathing rate is collected by measuring diaphragm expansion with a stretch sensor that functions as a variable resistor, connected to an Arduino micro-controller. If diaphragmatic breathing is present, a clear waveform can be distinguished in the data. The percentage of time that the participant is breathing correctly according to the task is taken as a measurement. Additionally, we examine the development of the waveform over time.

2.2 Virtual Environment

Our virtual environment is created with Unity 2017.2.0f3. and looks like a calm forest. This forest was made with the 'FantasyEnvironments' asset in Unity.

The participant sits in the virtual forest at one predetermined spot. A total of 13 randomly placed lights are visible.

In the conditions with biofeedback, the intensity of these lights reflects the participants diaphragm expansion through a connection between the Arduino and Unity, using the ARDUnity 1.0.8 asset. Breathing in correctly brightens the lights, and breathing out dims them. In the conditions without biofeedback the lights are off.

The head mounted display used in this experiment is the HTC Vive (2160x1200 pixels max, 90Hz, 110-degree field of view). We created a high and a low quality image within this same HDM by adjusting quality aspects within Unity, specifically the texture quality, shadow resolution, and density of details in the environment (see figure 1 and 2).

2.3 Procedure

Informed consent is obtained from all participants. Participants then receive a short instruction on deep, diaphragmatic breathing techniques and practice these shortly. Then the participant fills in the Trait Anxiety Inventory, puts on the stretch-sensor band and read the Velten Mood Induction sentences. The participant then rates the SUDS, the VR HMD is placed on the head of the participant and the first condition starts. Near the end of virtual experience the participant is asked to rate the SUDS again, followed by the removal of the HMD. The participant now again rates the SUDS and take a short break. Then, the same procedure is followed for condition two. After both the conditions the participant is debriefed.

Fig. 1. Experimental setup

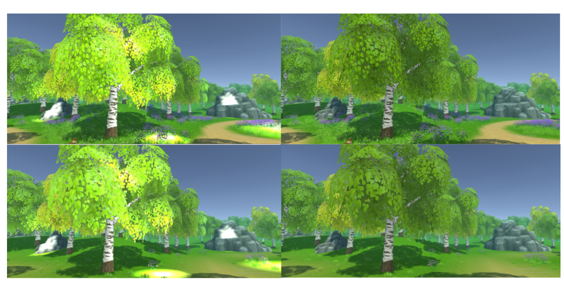

Fig. 2. Virtual environments. Top = high quality, bottom = low quality. Left = with biofeedback, right = no biofeedback.

3 Discussion

3.1 Preliminary results

During this exploratory pilot study, several trends were observed. Most importantly, there seems to be a wide range in individual responses to attention-management within virtual reality. While some participants indicated that they found the biofeedback lights calming and fun, others found them to be distracting. In general, if a participant did not achieve the correct deep breathing patterns, they tended to describe the lights as random, in one case even as annoyingly so. There were also some reports of novelty bias, were participants who hadn't experienced VR before reported feeling excited or nervous for that reason. This could potentially cloud the measurements.

SUDS scores tended to decrease during all virtual reality experiences, although this effect was not significant. In the non-biofeedback conditions, the SUDS score was slightly higher during the high-quality condition compared to lower quality, but this difference was also not significant. For these measurements, a full-scale study will hopefully bring more clarity.

Strong deep breathing patterns were very clearly observed in the diaphragm expansion data from several participants. In figure 3 you see an example of a participant who maintained deep breathing throughout the experiment, whereas 4 shows the patterns of a participant who self-reported that they didn't manage to achieve deep breathing. There were no strong trends observed in the deep breathing data related to the different conditions. There seem to be quite strong individual differences, so a large full-scale study might identify potential patterns more effectively.

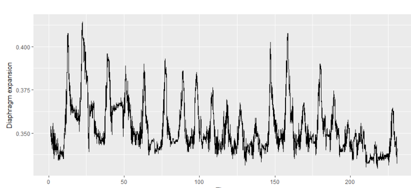

Fig. 3. Data from a participant who maintained deep breathing throughout

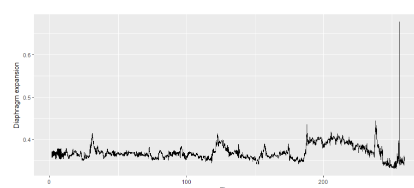

Fig. 4. Data from a participant who did not achieve deep breathing patterns

3.2 Research in Virtual Reality

The use of relatively new technologies and media in cognitive science comes with several challenges pertaining to experimental design. We will recount a few of our considerations here.

Firstly, the use of questionnaires could be detrimental to a users sense of presence in the virtual environment. It becomes more difficult to switch between virtual and non-virtual tasks, and could have unforeseen effects. Tools like the SUDS scale allow for a shorter assessment and verbal answer, allowing the user to maintain their sense of presence in the virtual world.

Secondly, the biofeedback used (breathing) can be measured in a variety of ways. One especially non-invasive option we explored was a temperature sensor under the nose - warm air signifies breathing out, cold air breathing in. We found however that the sensor did not responds quickly enough to the temperature changes. Another option would be to work with a microphone. This has the added advantage that it would be relatively easy to use with a smart-phone HMD, as the microphone is already a part of the device. However, this does not allow you to distinguish between deep diaphragmatic breathing and shallow chest breathing. The stretch sensor band is slightly constricting around the users abdomen, but does allow us to use biofeedback only when the user is breathing deeply. We constructed the stretch sensor ourselves using conductive thread, yarn and elastic band. This, together with the use of the Arduino micro-controller, results in a relatively affordable and accessible, yet reliable deep breathing sensor.

3.3 Future Applications

Should the full-scale version of this study show that not only high but also low quality VR indeed reduces anxiety significantly, it would be interesting to continue testing with actual smart-phones, preferably with low-priced accessible HMD's such as the Google Cardboard. Future research could additionally examine the influences of biofeedback lag, a smaller field-of-view, and alternative biofeedback sensors on the reduction of anxiety.

If our study shows that the way in which attention is redirected within the virtual world has an effect on anxiety reduction, the next logical step would be to repeat the study with an intervention that has a different goal in mind, such as directing attention away from the body. For example, one would hypothesize that for pain relief environments, a higher quality VR experience would work best, while adding biofeedback would negate the effects. In other words, the exact opposite result from the current study.

Another interesting avenue is the way biofeedback is placed within the virtual environment. Instead of the biofeedback visualization affecting the external virtual environment, it would be interesting to look at the effect of placing the biofeedback on the users virtual body. This could direct the users attention to their body even stronger. Alternatively, the biofeedback could be perceptualized in a way other than visually, for instance via audio.

If we elucidate the mechanisms behind what makes virtual reality health care intervention work in different scenarios, it could give us more information on which interventions can easily be made accessible and in which way. For instance, breathing exercises might be suitable to use with low-quality devices, while pain relief experiences might not. Giving the patient the possibility to experience the treatment wherever and whenever they want enormously increases their freedom and autonomy.

The development of the technology itself also means that these outcomes will continue to shift. The image-quality and processing capabilities of smart-phones is increasing every year. Rather than wait until smart-phone based HMD's have the same specifications as the high quality HMD's of today, we believe well researched, accessible VR based health applications can already be created in the coming years.

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