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ORIGINAL ARTICLE

A virtual reality approach to mindfulness skills training

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Abstract
Virtual reality (VR) is increasingly incorporated into psychotherapy, with the literature documenting its effectiveness in treating anxiety disorders, pain, and stress. Few studies have incorporated VR into mindfulness interventions. The present study examined the efficacy of VR in facilitating mindfulness. It was hypothesised that a brief mindfulness intervention integrated with VR would lead to a greater elevation in mindfulness than conventional mindfulness practice. Thirty-two adults (16 males) aged 18–65 ($M = 27.25$, $SD = 6.04$) were randomly allocated to either a control condition, in which participants listened to a mindfulness audio track, or an experimental condition, in which participants received mindfulness practice in a VR beach environment. The Toronto Mindfulness Scale (Lau et al. J clin psychol 62(12):1445–1467 2006) was used to assess two mindfulness factors: *curiosity* and *decentring*. Although participants in the experimental condition experienced an increase in mindfulness, VR was not significantly more effective in facilitating mindfulness overall, although the VR condition was characterised by a significantly greater increase in decentring. Replication and investigation of causative mechanisms is necessary to further understand the distinct increase in decentring observed during VR-enhanced mindfulness training in this study.

Keywords Mindfulness skills · Brief mindfulness intervention · Virtual reality · Toronto Mindfulness Scale · Randomised control trial

1 Introduction

Technologies such as virtual reality (VR) have made mental health interventions more accessible to the broader public (Hill et al. 2017). According to Burdea (1999), three factors have made the experience of VR compelling from a user standpoint: interaction, immersion, and imagination. First, the VR participant is actively able to interact with the VR environment. Second, VR is immersive, as demonstrated by its ability to elicit a sense of embodiment and presence in a virtual environment. Burdea and Coiffet (1994) state that "The imagination part of VR refers also to the mind's capacity to perceive nonexistent things" (p. 3). These components of VR may be leveraged to facilitate or enhance psychological therapies or skills practice in individuals who have experienced a lack of adherence to traditional psychotherapy (e.g. see Nararro-Haro et al. 2016).

An important factor in determining uptake of new technologies is technology acceptance (Davis 1989). According to Davis's (1989) technology acceptance model (TAM), two factors influence an individual's acceptance of technology: (i) perceived usefulness and (ii) perceived ease of use of the technology. Studies examining TAM about VR application in the field of mental health have demonstrated increased patient acceptance towards VR (Costaa and Carvalho 2004; Gracia-Palacios et al. 2007).

The benefits of VR in health care are well documented. Support for the effectiveness of VR in enhancing exposure-based therapies has been found across a range of psychological disorders, including anxiety disorders (Carlin et al. 1997; Gebara et al. 2016; Rothbaum et al. 1995, 2006) and post-traumatic stress disorder (PTSD; Aiken and Berry 2015; Difede et al. 2014; Ready et al. 2006). Other studies also support for the effectiveness of VR in managing pain and stress (Wiederhold and Wiederhold 2007; Wolitzky et al. 2005).

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However, one area in which the application of VR is not well documented is that of mindfulness skills training, with minimal studies exploring the effectiveness of VR in enhancing mindfulness (Nararro-Haro et al. 2016). Research done by Crescentini et al. (2016) demonstrated an increase in state mindfulness and decrease in stress response after participants were asked to observe stress-evocative VR scenarios after completion of an 8-week mindfulness meditation course. Yet, their work has called for future research due to the lack of replicated research into the use of VR to promote and/or administer mindfulness skills.

1.1 Mindfulness skills training

Mindfulness refers to present-moment awareness that is open, non-judgemental, and accepting of thoughts, feelings, and sensations (Brown et al. 2007; Davis and Hayes 2011; Malinowski 2008). Despite ambiguity found in definitions across the literature, the practice of mindfulness is based on the ability to observe one's cognitions, rather than actively engaging in thought and emotional response. According to Lau et al. (2006), (i) curiosity and (ii) decentring underlie the state of mindfulness. Curiosity refers to interest in the present moment, while decentring refers to the shift in attention or perspective away from one's external environment and towards one's inner experiences (Lau et al. 2006).

Mindfulness was first applied to clinical interventions by Kabat-Zinn (1982), who examined the effectiveness of a mindfulness-based stress reduction (MBSR) programme in treating patients with chronic pain. Extending this research to mindfulness-based cognitive behavioural therapy (MCBT), several randomised control studies have provided evidence for MBCT in reduction of avoidance behaviours and emotional regulation (i.e. the ability to appropriately express, and where necessary inhibit, emotion) in anxiety disorders (Evans et al. 2008; Goldin and Gross 2010), and reducing depressive symptoms and relapse in major depressive disorder (Hepburn et al. 2009; Teasdale et al. 2000). Linehan et al. (2006) found that self-harm behaviours among patients with borderline personality disorder (BPD) reduced with mindfulness intervention. Meta-analyses show that mindfulness-based intervention that involves a component of thought/emotional awareness is beneficial, with an indication of positive results in stress reduction (see Grossman et al. 2004), pain management (see Hilton et al. 2016), as well as overall therapeutic efficacy (see Khoury et al. 2013). Despite the broad efficacy of mindfulness treatments, there have arisen several issues with mindfulness as a construct. For example, some studies have highlighted low participant adherence to interventions, with dropout rates as high as 45% because of the amount of time a programme requires, with a typical standard being 8 weeks (Evans et al. 2008; Schoultz et al. 2015; Teasdale et al. 2000). Further, the effectiveness of mindfulness-based interventions may arise due to other treatment variables different from mindfulness techniques (e.g. relaxation skills learned in group or factors such as therapeutic alliance) and present in broader treatment programmes (Bernstein et al. 2012). Overall, mindfulness efficacy studies have not sufficiently differentiated the effect of specific mindfulness exercises from that of other elements of the treatment programme, such as cognitive behavioural therapy (CBT) techniques (Eagle 2008).

Compared to the literature on long-term mindfulness-based treatment, only a small number of studies have examined the efficacy of brief mindfulness exercises (Larson et al. 2013; Nyklicek et al. 2012; Rahl et al. 2017). Randomised control trials of brief mindfulness exercises have supported their therapeutic effect (Broderick 2005; Call et al. 2013; Tan et al. 2014). For example, Broderick (2005) found that a brief mindfulness meditation exercise, which involved participant awareness of their thoughts and listing these on a notepad, was more effective than distraction or rumination response tasks in increasing mindfulness skills and reducing negative affect (NA) following a negative mood induction, which involved participants reading out loud negative/depressing statements.

A potential barrier that is identified with the application of brief mindfulness interventions is the increased self-regulatory effort and sustained attention required in initial sessions of practice (Lutz et al. 2008; Tang et al. 2015). Hence, exploring techniques that offset the attentional effort in practising mindfulness can enhance acquisition of mindfulness skills and increase the potential benefits of brief mindfulness practices (Nararro-Haro et al. 2016; Lymeus et al. 2016). As noted earlier, virtual reality (VR) constitutes one potentially useful technology for enhancing brief mindfulness practice (Nararro-Haro et al. 2016).

1.2 A virtual reality approach to brief mindfulness skills training

Nararro-Haro et al. (2016) explored the feasibility and clinical utility of using VR to enhance mindfulness skills in dialectical behaviour therapy (DBT), an approach that incorporates mindfulness techniques in conjunction with more common behavioural and cognitive interventions. In their single-participant case study, the client, a 32-year-old woman diagnosed with borderline personality disorder, floated down a three-dimensional virtual river while listening to a DBT training mindfulness-based audio track. The authors noted that patient markers of depression and urge for self-harm reduced post-session. The patient also demonstrated high adherence and self-reported the experience as beneficial. Notably, as this was a case study, results cannot be generalised more broadly. However, the preliminary outcomes of that work are promising and certainly highlight

the need to explore the potential of VR-supported mindfulness in more depth.

We propose that the next step is to explore the efficacy of VR-enhanced brief mindfulness practice using a larger sample and systematic experimental methods. VR research has commonly been limited to laboratory or clinical studies, which require participants/patients to attend for a session. From a mindfulness intervention standpoint, this has been problematic as many mindfulness practices are portable and transferrable across environments (for instance, MP3 sessions, group workshops, and ad hoc practice). In spite of this, with technological improvements the availability of more versatile VR systems is increased; thus, a forward-looking step is to adopt a method of delivery of virtual environments on viewing devices that are more portable, accessible, and affordable for people (Nararro-Haro et al. 2016; Rauterberg 2004). Initial approaches that could lend themselves to more portable application such as Gromala et al. (2015) "Virtual Meditative Walk" (VMW) can be considered here.

The present study aimed to determine whether a brief mindfulness intervention integrated with VR enhances mindfulness in novice participants. We hypothesised that a VR environment combined with a mindfulness audio track would facilitate an increase in mindfulness, as measured via self-report. We also hypothesised that mindfulness practice guided within a VR environment would lead to a greater increase in mindfulness than that of conventional mindfulness practice. As a final open-ended aim, we assessed the general efficacy of mindfulness skills training applied within a VR context.

2 Method

2.1 Participants

The sample comprised 32 participants (16 males) aged between 18 and 65 ($M = 27.25$ years, $SD = 6.04$). The participants were recruited from RMIT University and the general population of metropolitan Melbourne, Australia. Individuals with (i) a history of psychiatric or neurological disorders; (ii) a history of psychological treatment; (iii) prior experience with virtual reality or mindfulness training; or (iv) hearing or visual impairments were excluded from participation. All participants were volunteers and were provided with a $20 gift card in gratitude.

2.2 Materials

For the VR experience, an Oculus Rift head-mounted display (HMD) was connected to an Alienware desktop computer optimised for VR testing. The VR experience was generated by a video titled "A Walk on the Beach", designed by Eric Fassbender at 360°/VR video producer Atmosphaeres. The video displayed a 360° spherical landscape view of South Australia's coastal suburb of Port Noarlunga at midday (Fig. 1). Audio recording for mindfulness exercise on "external world and breath" was obtained from the *Counselling and Psychological Resources* section of the University of Melbourne website (University of Melbourne 2017). All software analyses were performed using the SPSS statistical package, version 22 (IBM Corp, Armonk, USA).

The *Toronto Mindfulness Scale (TMS)*, a self-report questionnaire, was used to measure each participant's state mindfulness. The scale included 13 items pertaining to subjective awareness and referenced to the immediate mindfulness session. Two sub-scales were computed: *curiosity*, reflecting an attitude of interest (e.g. "I am curious about each of my thoughts and feelings as they occur"), and *decentring*, reflecting a shift from identifying personally with cognitions and feelings of one's experience (e.g. "I am receptive to observing unpleasant thoughts and feelings without interfering with them"). Participants rate how well each statement represented his/her experience before and after the brief mindfulness exercise from 0 (*Not at all*) to 4 (*Very much*). Higher scores on each subscale indicate a higher level of the relevant construct (Lau et al. 2006).

2.3 Design

Participants were randomly allocated to either a VR ($n = 16$) or non-VR ($n = 16$) condition. A within-subjects approach was taken to test for elevation in mindfulness, with measurement conducted at pretest and post-test. A between-subjects element was used to compare the VR (experimental) and non-VR (control) conditions. Self-reported state mindfulness was used as the dependent variable.

Fig. 1 A screenshot from "*A Walk on the Beach*" virtual relaxation video

2.4 Procedure

Ethics approval was granted by RMIT University. Upon approval, individuals contacted the researcher and were invited to participate in the study. Data collection took place at RMIT University's city campus, in a quiet room with proper lighting and air conditioning. Before administering the questionnaires, a short introduction was provided regarding the study. Participants were randomly assigned to either the VR or the non-VR group and were required to complete basic demographic information along with the Toronto Mindfulness Scale (TMS). Participants were then instructed to engage in the session of mindfulness skills training.

Participants in the control group listened to the mindfulness training audio track; these participants were instructed to close their eyes during the exercise, or to direct their gaze downward or steadily at a single location. Participants in the experimental group listened to the same mindfulness training audio track while immersed in the "A Walk on the Beach" 360 video/VR experience. Participants were not required to engage with the 360 video/VR experience and were instead instructed to passively observe the video of beach scenes in front of them. Participants in both conditions were instructed to maintain a comfortable posture throughout the exercise.

Both groups were guided through instructions and engaged in the mindfulness training exercise of focusing on the external sensations and their breath. The duration of the mindfulness exercise was approximately 20 min. Following the exercise, participants again completed the TMS as a post-test measure. At the completion of the study, participants were debriefed about the purpose of the project. Data were collected using the Qualtrics survey programme over the course of 4 weeks from 31 June to 31 August, 2017.

3 Results

No missing data were present. Two variables were not normally distributed (pretest curiosity and pretest total mindfulness). As n > 15 and the data were continuous, nonparametric tests were not included in this instance.

The mean and standard deviation scores for total mindfulness, curiosity, and decentring across experimental and control groups are displayed in Tables 1 and 2.

Paired sample t tests indicated that in the VR condition, total mindfulness is significantly increased from pretest to post-test, $t(15) = -5.20$, $p < .05$ (Table 2). This effect was also present in the non-VR condition, $t(15) = -3.83$, $p < .05$ (Table 3). Between-group t tests indicated that the increase in total mean scores of mindfulness was not significantly different between the experimental and control groups, $t(30) = 1.32$, $p = .195$ (Table 3).

Regarding the TMS sub-scales, curiosity did not significantly improve from baseline in either conditions, VR ($t(15) = -1.74$, $p = .102$) or non-VR ($t(15) = -1.51$, $p = .152$), and hence no significant difference in change to curiosity was detected, $t(30) = -.09$, $p = .932$. In contrast, decentring increased from baseline scores in both VR ($t(15) = -6.60$, $p < .05$) and non-VR conditions ($t(15) = -4.23$, $p < .05$). Moreover, VR participants ($M = 26.63$, $SD = 2.25$) showed significantly higher decentring compared to non-VR participants ($M = 23.88$,

Table 1 Descriptive statistics and within-subjects mindfulness differences in the VR condition ($n = 16$)

Outcome measure	Pretest		Post-test		95% CI for mean difference	
	M	*SD*	*M*	*SD*	Lower	Upper
Total mindfulness	36.50	9.87	47.31	5.50	−15.25	−6.38
Decentring	17.81	4.92	26.63	2.25	−11.66	−5.96
Curiosity	18.69	6.36	20.69	4.39	−4.45	.44

M mean, *SD* standard deviation

Table 2 Descriptive statistics and within-subjects mindfulness differences in the non-VR condition ($n = 16$)

Outcome measure	Pretest		Post-test		95% CI for mean difference	
	M	*SD*	*M*	*SD*	Lower	Upper
Total mindfulness	38.31	7.87	44.69	5.71	−9.93	−2.83
Decentring	18.56	4.50	23.88	3.54	−7.99	−2.63
Curiosity	19.75	5.20	20.81	3.87	−2.56	.438

M mean, *SD* standard deviation

Table 3 Independent sample *t* test comparing outcome measures for the experimental and control groups

		t	*df*	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference	
							Lower	Upper
Total mindfulness	Equal variances assumed	1.324	30	.195	2.6250	1.9821	−1.4230	6.6730
Decentring	Equal variances assumed	2.625	30	.014	2.7500	1.0478	.61008	4.8899
Curiosity	Equal variances assumed	−.085	30	.932	−.12500	1.4633	−3.1134	2.8634

SD = 3.54), $t(30) = 2.63$, $p < .05$) (Table 3). Cohen's *d* was estimated at .96, a large effect (Cohen 1992).

Of the 16 participants in the experimental condition, 11 reported that the HMD was somewhat uncomfortable to wear and that their attention was drawn to the band around their head. These technological limitations, thus, may have reduced the sense of presence in mindfulness training which, in turn, reduced the efficacy of VR.

4 Discussion

The present study examined whether a VR environment could enhance brief mindfulness intervention. The results indicated that participants in each condition had significantly greater improvements in self-reported mindfulness from baseline scores. Therefore, our first hypothesis, which purported that participants in the VR condition would report an increase in state mindfulness, was confirmed. Our second hypothesis, which proposed that the VR condition would produce an increase in mindfulness skills above and beyond that of traditional practice, was partially confirmed. Namely, we found greater increases in decentring, a subordinate construct of mindfulness, in the VR condition compared to the non-VR condition. Our overall findings indicate that VR practice is a viable means of delivering mindfulness skills.

The results related to our first hypothesis are consistent with research conducted by Nararro-Haro et al. (2016), which demonstrated the effective use of VR and brief mindfulness practice. Although the research of Nararro-Haro et al. was centred on a case study, our results provide further evidence in support of VR-aided mindfulness skills practice in a controlled experiment. This suggests that VR-aided mindfulness skills practice is a viable alternative or supplemental approach to traditional intervention.

The results pertaining to our second hypothesis showed that VR-aided mindfulness practice produced minor benefits above and beyond traditional practice, increasing decentring, but not curiosity. Previous research has identified decentring as a working mechanism of mindfulness in which one actively experiences a diffusion from one's cognitive and emotional states (Carmody et al. 2009; Hayes-Skelton and Graham 2013; Lau et al. 2006). According to Shapiro et al. (2008), decentring enables the distancing of oneself from conscious thoughts by perceiving them as temporary experiences rather than actual manifestations of reality and self. The finding of greater increases in decentring as a function of VR mindfulness, therefore, could provide a foundational framework for the potential therapeutic importance of VR mindfulness, specifically, in the context of mood disorders, wherein cultivating decentring may enable individuals to diminish negative thoughts and rumination (Lau et al. 2006).

Notably, the above result calls for future replication and broader exploration in order to draw more meaningful conclusions. Although overall mindfulness was not significantly impacted by the VR practice, considering that only one subscale showed a substantial increase in mindfulness, we suggest that researchers consider other sub-scales in their work on VR intervention. Definitions of curiosity and decentring need to be more closely critiqued in terms of whether both contribute equally to therapeutic effects (not directly measured in our study as we have made the assumption that mindfulness constructs have been well established in prior work). For example, it may be that mindfulness therapy need only elicit change in one of the sub-scales of mindfulness. A comparison across metrics/scales could highlight which other dimensions are most influenced in VR as compared with traditional practice.

4.1 Limitations and conclusion

From our findings, we conclude that VR-based mindfulness intervention is at least as effective as standard mindfulness practice. Investigation into VR-enhanced mindfulness has not been broadly conducted previously in a controlled experimental design, which serves as one strength of the current study. Specifically, these results pave the way for future explorations into VR-aided counselling and intervention. VR technologies are gaining in popularity with the recent releases of mass-market, commercially available headsets, and VR-aided therapies have become more common in clinical settings. The present research provides a basis for considering the efficacy of implementing a VR-aided mindfulness

skills intervention in public health and/or clinical treatment programmes.

One limitation of the present study is the sample size of 32 participants. This can be regarded as a relatively small sample in comparison with much larger samples in related research on brief mindfulness (e.g. Call et al. 2013, $N=91$; Tan et al. 2014, $N=72$) and VR interventions for other conditions (e.g. Herrero et al. 2014, $N=40$). The smaller sample size limits both the precision of the estimates and the generalisability. Similarly, we only compared laboratory-administered mindfulness skills training in this study, rather than comparing the outcomes of a clinical session, or series of sessions, with VR-supported mindfulness treatment. This makes the research less ecologically valid, and generalising the findings to the therapeutic context is therefore not yet possible.

A concern from the outset of the study was that the VR component of mindfulness practice could in fact reduce participant mindfulness due to distractions either in the VR environment or due to external factors. It is promising to note that, despite minor distractions due to discomfort of the headset, the impact of mindfulness training in the experimental condition was not influenced. Qualitative feedback from our VR participants indicated that a more pressing distraction was the comfort of the VR headset, suggesting that participant comfort should be a core priority when selecting a VR headset with which to enhance mindfulness exercises, and that participants could benefit from additional time spent habituating to and adjusting the feel of the VR headset.

In conclusion, the current study demonstrated the feasibility of VR to facilitate mindfulness skills practice. The findings suggest that the VR-based mindfulness intervention is as effective as a standard mindfulness practice to enhance state mindfulness. They also indicate greater increases in decentring skills as a function of VR mindfulness training. VR-based interventions based on mindfulness-skills training have the potential to be cost-effective, flexible, and accessible to a broader audience. Further explorations and larger randomised control trials are necessary before such interventions can be fully endorsed for use in clinical practice.

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