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ORIGINAL PAPER

# Meditating in Virtual Reality 3: 360° Video of Perceptual Presence of Instructor

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## Abstract

**Objectives** The need for remote delivery of mental health interventions including instruction in meditation has become paramount in the wake of the current global pandemic. However, the support one may usually feel within the physical presence of an instructor may be weakened when interventions are delivered remotely, potentially impacting one's meditative experiences. Use of head-mounted displays (HMD) to display video-recorded instruction may increase one's sense of psychological presence with the instructor as compared to presentation via regular flatscreen (e.g., laptop) monitor. This research therefore evaluated a didactic, trauma-informed care approach to instruction in mindfulness meditation by comparing meditative responses to an instructor-guided meditation when delivered face-to-face vs. by pre-recorded 360° videos viewed either on a standard flatscreen monitor (2D format) or via HMD (i.e., virtual reality [VR] headset; 3D format).

**Methods** Young adults ($n$ = 82) were recruited from a university introductory course and experienced a 360° video-guided meditation via HMD (VR condition, 3D format). They were also randomly assigned to practice the same meditation either via scripted face-to-face instruction (in vivo [IV] format) or when viewed on a standard laptop display (non-VR condition, 2D format). Positive and negative affect and meditative experience ratings were self-reported and participants' maintenance of focused attention to breathing (i.e., meditation breath attention scores [MBAS]) were recorded during each meditation.

**Results** Meditating in VR (3D format) was associated with a heightened experience of awe overall. When compared to face-to-face instruction (IV format), VR meditation was rated as less embarrassing but also less enjoyable and more tiring. When compared to 2D format, VR meditations were associated with greater experiences of relaxation, less distractibility from the process of breathing, and less fatigue. No differences were found between VR and non-VR meditation in concentration (MBAS). Baseline posttraumatic stress symptoms were risk factors for experiencing distress while meditating in either (VR and non-VR) instructional format. Of those who reported a preference for one format, approximately half preferred the VR format and approximately half preferred the IV format.

**Conclusions** Recorded 360° video instruction in meditation viewed with a HMD (i.e., VR/3D format) appears to offer some experiential advantage over instructions given in 2D format and may offer a safe—and for some even preferred—alternative to teaching meditation face-to-face.

**Keywords** Virtual reality (VR) · 360°-video · Meditation · Mindfulness · Presence · COVID-19

Most people associate *virtual reality* (VR) with immersive computer graphical environments that are viewed through a head-mounted display (HMD). An emerging body of work is demonstrating the efficacy of conducting meditation practices within these graphical virtual environments, especially for improving positive affect and wellbeing (e.g., relaxation; Frewen et al., 2020; Mistry et al., 2020; Navarro-Haro et al., 2017, 2019). For example, Mistry et al. (2020) showed that, as compared to closely matched non-VR meditations, VR meditation was associated with heightened experiences of certain positive emotions, most notably awe, particularly when the VR meditation preceded rather than followed practice of the non-VR meditation in a repeated measures design. This emerging program of research demonstrates the potential for guided

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meditation, when conducted in graphical virtual environments, to evoke salient experiences of positive affect when compared to practicing meditation outside the context of VR. Further, VR meditations were regarded as credible interventions for mental health problems including for trauma- and stress-related disorders (e.g., PTSD, depression, anxiety, and dissociative disorders; Mistry et al., 2020).

Apart from virtual computer graphical environments, another form of delivering immersive VR experiences involves acquiring real-world audiovisual footage in 360° for subsequent playback via HMD, that is, 360° videography. By definition, such footage may appear more realistic to users in comparison to computer simulated environments, which is relevant in so far as perceived realism is one factor involved in the multidimensional experience of presence within virtual environments (e.g., compare the "ecological validity" factor in the *Sense of Presence Inventory* developed by Lessiter et al., 2001). For example, previous researchers asked participants to follow a guided meditation while immersed into 360° videos of pleasant surroundings (i.e., a rocky landscape with mountainous backdrop) and found that participants experienced a minimal degree of anxiety during the meditation as assessed by self-report and both EEG increases in alpha and decreases in beta power. However, in this study, few differences were found even in comparison with a silent resting condition, thus confounding the link between the two psychological states (Tarrant et al., 2018). Another example is provided by Bennett (2018) who also found that, although participants reported a high degree of presence while meditating and viewing a 360° video of a beach scene, they did *not* report experiencing a greater degree of relaxation or other positive emotions when compared to a group of participants who practiced the same meditation administered in audio only (i.e., without wearing a HMD at all). These initial studies suggest that, in contrast to VR meditations that use computer graphics environments, practicing meditation while viewing 360° video footage of pleasant real-world environments may produce relatively equivalent affective responses when compared to similar meditations conducted without VR. Simply stated, when it comes to self-reported affective responses to meditation, meditating while viewing 360° videos of pleasant environments through a HMD seems to be neither better nor worse than traditional meditation or simply resting.

Although one might conclude that non-significant differences between responses to 360°-video VR and non-VR meditation may indicate a lack of support for the former, a finding of general equivalence between these conditions may still be a basis for advocating the use of 360°-video VR as a feasible and accessible alternative to delivering traditional face-to-face meditation interventions, without compromising effectiveness (e.g., Rizzo & Shilling, 2017). Such considerations have become especially relevant in the wake of the current global COVID-19 pandemic where, at the time of this writing, the need to physically distance to prevent the spread of the virus has limited opportunities for face-to-face contact, including within the context of providing care for mental health problems such as via instruction in guided meditation practices. Indeed, Riva and Wiederhold (2020) discussed how VR wellbeing exercises such as relaxation and meditation could be applied to help overcome distress and negative affect associated with COVID-19 during the quarantine period, which they argue has been linked to social and existential losses for many individuals. In short, if your usual, preferred practice is to meditate while sitting at a public beach that you can no longer access due to health and safety regulations, or for fear of viral infection and other conditions, viewing of an immersive 360° audiovisual recording of a similar environment via HMD might constitute a safe alternative that offers both a sense of presence in the environment and engenders relatively comparable affective responses (e.g., relaxation, mindfulness; Bennett, 2018; Riva & Wiederhold, 2020).

Nevertheless, as a possible shortcoming inherent to all previous evaluations of VR applications to meditation, the virtual environments have been depicted only in solitude, in other words, no other persons (including even the instructor who is guiding the meditation) are visually depicted in the virtual scenes. This may be a limitation in so far as meditating alone vs. while in the company of another person(s) can differentially impact one's meditative experiences (Schnurr & Montgomery, 2010), for example, in terms of experienced levels of closeness and trust in others (Bowen & Kurz, 2011; Peilot et al., 2014). In fact, qualitative and longitudinal research conducted by Solhaug et al. (2016) discovered that instructor presence may help novice meditators increase their confidence, attitudes, and commitment toward in-person meditation, illustrating the unique value of practicing with others. This is further consistent with the emphasis on "sangha" (the community of practitioners) during meditation practice in Buddhist psychology, which is considered to be one of the three so-called jewels of this path, together with Buddha (the teacher) and Dharma (the teachings) (Lauricella, 2014). Indeed Lauricella (2014) noted that in-person, face-to-face instruction was preferred to audio recorded instruction by as many as half of participants in a university classroom offering of mindfulness instruction. It is simply not known, however, whether these findings would also apply in the case of the physical vs. *visual* presence of an instructor, for example, as could be captured by recording a 360° video of an instructor-guided meditation. In fact, to our knowledge, no published research has investigated how the experience of being guided in the practice of meditation might differ when such instruction is provided in the traditional way of live face-to-face interaction vs. as a playback of a previously recorded 360° video of the same instructor guiding a meditation, viewed either via HMD or standard flatscreen (e.g., laptop) monitor, albeit that some early work piloted the use of avatars

in this context (e.g., Cikajlo et al., 2016), and research has provided proof of concept of the use of VR for inducing body swap illusions in the conduction of self and other compassion (Cebolla et al., 2019) and provided a basis for further investigations into this emerging area of potential technological applications in mindfulness instruction.

Especially within the present context of the global COVID-19 pandemic and the associated need to restrict social contact, the importance of evaluating different virtual methods for delivering interventions that promote positive affect and wellbeing, such as guided meditation, has become salient. The current research therefore compares the immediate affective impact of delivering instructor-guided meditation practices via three methods: (1) traditional face-to-face (in vivo [IV] method), (2) pre-recorded 360° video viewed by standard laptop computer monitor (2D format), and (3) pre-recorded 360° video viewed through a HMD (VR condition; 3D format). We also evaluated individual differences in response to the meditations in terms of participants' self-reported PTSD symptoms due to previous findings that the presence of PTSD symptoms at baseline represents a risk factor for experiencing distress during meditation both outside (Zhu et al., 2019) and inside (Mistry et al., 2020) the context of VR. In this context, the psychological significance of instructor-guided meditation practices may be of particular relevance to persons who have experienced interpersonal trauma (e.g., being the victim of physical or sexual assault) who consequently tend to be less trusting within relationships (Williams et al., 2014), possibly lowering their ability to benefit from instruction in meditation.

## Method

### Participants

The study included a convenience sample of 82 undergraduate students, recruited through the university's research participation pool, consisting of 50 women and 32 men ranging in age from 17 to 28. Half of the group described themselves as White with the remaining participants being of diverse ethnicity. Referring to meditation practice, the great majority (86%) of participants reported "never" meditating while about one in ten reported meditating "but not not regularly (less than once a week)."

### Procedures

The present study was approved by the research ethics board of Western University, Canada. Participants were invited to participate in the study by an advertisement displayed on the university's research participation website. Interested participants signed up for timeslots via the website and met individually with the experimenter at a predetermined location on the university's campus, providing written informed consent prior to participating. Participants were compensated with partial course credit toward an introductory psychology course.

Participants first completed a battery of baseline surveys termed *Pre-Meditation Surveys* in the "Measures" section described subsequently.

They were then randomly assigned to complete two guided meditation sessions, either VR or non-VR in counterbalanced order. In other words, all participants completed a scripted, pre-recorded 360° guided meditation by using a VR HMD (i.e., VR, #D format) either first or second, and each participant completed a non-VR version of the same scripted guided meditation, performed either as a live face-to-face session (i.e., in vivo [IV] format) or by watching the pre-recorded 360° video via a laptop monitor and headphones (i.e., 2D format). In any case, all three formats of the guided meditation lasted approximately 5 min and referred to scripted, trauma-informed meditation instructions that were kept consistent across each session.

After each individual meditation, participants were then asked to complete another battery of questionnaires measuring their subjective responses to the meditation termed *Post-Meditation Surveys* as described subsequently. They were also briefly interviewed about what they experienced during the meditations with an open question: "Overall, how much did you feel the two types of meditations differed? Any comments, questions, concerns, or criticisms?" Regarding the latter, qualitative feedback was transcribed by the experimenter for subsequent analysis.

Referring to technical specifications, the HMD used for the VR-360° (3D format) meditation was a Samsung Gear Headset powered by a Samsung Galaxy 10+ smartphone which optimized the HMD specification to accommodate a pixel resolution of 1280 × 1440 per eye, including a refresh rate of 60 Hz and a 101° field of view. Participants also wore over-ear noise cancelling headphones to listen to the audio instructions that were given in both 3D and 2D formats.

The 360° guided meditation videos were narrated and pre-recorded by the first two student authors using a "GoPro Fusion" 360° camera, each in their respective lab environments where the face-to-face meditation was also carried out, thus ensuring equivalence of surroundings between viewing conditions. Videos were rendered as .mp4 files in 5.2 k resolution processing at 30 frames per second with 360° spatial audio using the GoPro Fusion Studio application. Pitch was lowered to − 0.85 in order to level the spherical video and orient the horizon to an even plane. The same videos were used in the display of the 2D and 3D formats; the only difference was thus whether the video was viewed by HMD (in the case of the 3D format) or by standard laptop (2D format). These videos will be included in the supplementary materials after the blinded review is completed.

The content of the videos included meditation instruction consistent with a trauma-informed care approach to guided practice, as supervised by the corresponding author, a psychologist with expertise in assessing and treating PTSD. The meditation primarily involved guiding participants through a mindful breathing exercise along with the collection of meditation breath attention scores (MBAS; Frewen et al., 2008). Specifically, a meditation bowl was sounded three times at regular intervals throughout the 5-min meditations to prompt participants to raise one, or another, finger on their left or right hand which indicated whether their attention was focused on their breathing or if they had become distracted, respectively. At the end of the study, a total MBAS from 0 to 3 was tallied separately in response to the VR and non-VR meditations to be statistically compared.

For all conditions, the instructor remained in the room to ensure safety that participants were not experiencing undue distress and to maintain that participants were actively participating in the meditative exercises. At the end of the study, participants were thanked for their time and efforts.

## Measures

### Pre-meditation Surveys

**Life Experiences Survey** Whether each of 47 non-traumatic life stressors had occurred for participants within the last year was assessed using the Life Experiences Survey (LES) (Sarason et al., 1978) which asks about such life events as "marriage," "detention in jail or comparable institution," and "death of spouse." Participants answered by either "No," "Yes, at least once," or "Yes, many times" to each life event description scored 0, 1, and 2, respectively, although the number of different types of events participants had experienced is reported as a binary response (0 vs. 1 or 2).

**Life Events Checklist for DSM-5** Which, if any, of a list of 17 different potentially traumatic events participants had experienced was surveyed using the extensively validated Life Events Checklist for DSM-5 (LEC-5) (Weathers et al., 2013), which includes as examples "serious accident at work, home, or during recreational activity" and "natural disaster (for example, flood, hurricane, tornado, earthquake)." The same response options were used as for the LES.

**Adverse Childhood Experiences Questionnaire** Administering the Adverse Childhood Experiences (ACE) questionnaire queried which (if any) of a list of 10 different categories of caregiver dysfunction, abuse, and neglect that each participant reported experiencing during their childhood (Felitti et al., 1998). Examples of ACE include "often or very often feeling that no one in your family loved you or thought you were important or special… Or your family did not look out for each other, feel close to each other, or support each other." The same response options used for the LES and LEC-5 were used to the ACE survey.

**Posttraumatic Stress Disorder Checklist for DSM-5** How often in the last-month participants had experienced the various 20 symptoms of PTSD was assessed using the Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5) (Blevins et al., 2015). Participants referred to a 5-point Likert scale (0 = "*Not at all*" to 4 = "*Extremely*") in order to make their frequency reports for each symptom. The present study utilized the recommended cut-off score of at least 33 to determine probable PTSD status (Weathers et al., 2013).

**Trauma-Related Altered States of Consciousness Items** Participants' were also asked about dissociative experiences using the 10-item trauma-related altered states of consciousness (TRASC) survey (Frewen et al., 2017; Frewen & Lanius, 2015), using the same Likert scale ratings as used to collect responses to the PCL-5. Together with a $\geq 33$ score on the PCL-5, participants were described as probably meeting diagnostic criteria for the dissociative subtype of PTSD when they also scored at least 3 on at least one of depersonalization and derealization items validated for such assessment by Frewen et al. (2015).

### Post-meditation Surveys

We note at the outset that responses to post-meditation surveys were always scored at the item level rather than as various sub-scale or total-scale summary scores as is more conventional in the literature. This approach, following previous methods (e.g., Mistry et al., 2020), is preferred to allow a more nuanced investigation of self-reported meditative experiences.

**Satisfaction and Credibility Questionnaire** Ten questions surveying participant satisfaction with and perceived credibility of each meditation as an intervention for mental health disorders and increasing general wellbeing were administered as described by Frewen et al. (2015). Response options were the same as for the PCL-5 and TRASC surveys.

**Modified Differential Emotions Scale** The 20-item modified Differential Emotions Scale (mDES) (Fredrickson et al., 2003) was administered to assess positive and negative affective responses to the VR and non-VR meditation separately; 10 of the items assess various positive emotions (e.g., "Awe, Wonder, Amazement") while the remaining 10 items assess various negative emotions (e.g., "Stressed, Nervous, Overwhelmed"). Response to these affective descriptions was measured using an 11-point scale (0 = "No, not more than usual" and 10 = "Yes, much more than usual"). These item anchors were used in order to compare response to the

meditation as a deviation from baseline, normative experience as was also conducted in the study by Zhu et al. (2019), allowing a more direct comparison to their previous findings.

**Buddhist Affective States Scale** The Buddhist affective states scale (BASS) consists of 10 items that have been used in some recent studies to assess affective states described within Buddhist psychology that were not included in the mDES, a questionnaire first used in the study by Zhu et al. (2019). Sample items from the BASS include "Oneness, unity, connectedness" and "Sacredness, reverence, spiritual," and the degree to which participants experienced such states was measured using the same 0–10 scale used for the mDES, affording direct comparability.

**Meditative Experiences Questionnaire** Finally, whereas the BASS sought to assess various meditative experiences of special relevance to Buddhist psychology, the Meditative Experiences Questionnaire (MEQ) has been used in several previous studies to inquire about normative, everyday kinds of meditative experiences (Frewen et al., 2011) such as relaxation, mind wandering, physical discomfort, and fatigue; again, the present study inquired about such experiences using the same method of response used for the mDES and BASS.

## Data Analyses

The design of the present study involved one within-group repeated measures independent variable, namely, TYPE of guided meditation (i.e., VR vs. non-VR). In other words, both VR and non-VR meditations were administered to all participants. The study also included two between-subject independent variables, specifically, the ORDER in which participants were randomized to complete the two meditations (i.e., whether the VR meditation was administered before or after the non-VR meditation), and whether or not the non-VR meditation was completed face-to-face (IV format) or, if instead, it also involved video playback but viewed on a standard flatscreen monitor instead of the VR-HMD (2D format). Finally, the study involved six groups of dependent variables assessed by numeric ratings, specifically, positive affect (mDES-PA), negative affect (mDES-NA), Buddhist affective states (BASS), normative meditative experiences (MEQ), meditation breath attention scores (MBAS), and a general satisfaction survey first used by Frewen et al. (2015) that was in turn modeled after the questionnaire developed by Devilly and Borkovec (2000). Taken together, this is the very same experimental model and set of dependent measures as was undertaken by Mistry et al. (2020), with the addition of MBAS, and thus constituted a comparison study whereby the previous publication utilized the display of computer simulated environments, whereas the current study depicted 360° videos of pre-recorded instructor-guided meditations. Also following the methods undertaken in the previous study (Mistry et al., 2020), we surveyed responses to the VR and non-VR meditations at the item level using multivariate ANOVA to control for multiple comparisons with two-tailed statistical significance determined at $p < .05$ for analyses of variance and post-hoc tests of means (2-tailed). Inferential statistics ($F$ and $t$) are fully reported in the supplementary materials, whereas the main text reports obtained effect sizes (partial eta-squared [$\eta^2$-$p$]) only for those effects that met conventional statistical significance. Correlations between self-reported PTSD symptoms and response to the meditations are also reported as statistically significant at two-tailed $p < .01$.

Responses to the open-ended question were also examined using a positivist approach to thematic analysis (e.g., Boyatzis, 1998; Guest et al., 2012) generally following the procedures used by Mistry et al. (2020). Specifically, two student researchers independently identified thematic codes within participants' responses that were compiled into a finalized set with input from the supervising psychologist. Participant responses were then reread by the student researchers to identify examples of the codes, and all instances of disagreement were coded in final by the supervising psychologist. Here, we further analyze only those codes that were identified at least 8 times (i.e., in dialogue with approximately a minimum 10% of participants), with the further requirement that the number of observations was at least twice the number of original disagreements between the student raters. Such observations were compared for frequency of occurrence between the VR and non-VR conditions in reference to the chi-square statistic.

## Results

Participants self-reported having experienced a range of stressful live events (0–22; $M = 10.02$, $SD = 4.89$), traumatic life events (0–8; $M = 1.28$, $SD = 1.40$), and adverse childhood experiences (0–4; $M = 0.71$, $SD = 1.07$). Moreover, participants self-exported a range of DSM-5 PTSD symptoms (0–67; $M = 16.29$, $SD = 16.79$). Further, 18 participants, approximately one in every five (22%), scored above the currently recommended cut-off of 33 for probable DSM-5 PTSD diagnosis on the PCL-5 which is within the range of what can be expected from previous research in other groups of similarly recruited participants (Mistry et al., 2020; Zhu et al., 2019). Among this subsample of 18, four (22%) met probable diagnosis of the dissociative subtype of PTSD (D-PTSD) indexed by a score of at least three on at least one of the two TRASC items described by Frewen et al. (2015). MANOVA provided no indication that the groups differed at baseline on any of these clinically relevant measures (i.e., implying that the reader may assume that grouping conditions did not differ at baseline despite randomization). Participants randomized to

complete the VR meditation first numbered $n = 45$, while the remaining $n = 41$ completed the VR meditation second.

**Positive Affective States** At the multivariate level, the within-group main effect of meditation TYPE (VR vs. non-VR) was statistically significant ($\eta^2$-$p = .30$) in the absence of any significant interactions or main effects of the between-grouping factors of ORDER or LIVE/VIDEO. At the univariate level, however, meditation TYPE was statistically significant only for one of the ten positive emotions surveyed, specifically, in the sole case of "awe, wonder, amazement" ($\eta^2$-$p = .15$), which replicates results previously seen for the computer simulated environments studied by Mistry et al. (2020). A follow-up paired $t$-test indicated that the VR-360° meditation was more provocative of awe than was the non-VR meditation, $d' = .49$. Results for all positive emotions surveyed are displayed in Fig. 1 for comparison purposes.

**Negative Affective States** At the multivariate level, only the interaction between meditation TYPE (VR vs. non-VR) and the LIVE/VIDEO condition was statistically significant ($\eta^2$-$p = .23$). Moreover, at the univariate level, the interaction was statistically significant only for one of the ten negative emotions surveyed, specifically, solely in the case of "embarrassed, self-conscious, blushing" ($\eta^2$-$p = .05$). Here, follow-up between-group differences were found to be non-significant regarding feelings of embarrassment in response to both VR, $t(80) = 1.52$, $p = .13$, and non-VR meditations, $t(80) = 0.30$, $p = .76$. Further, among participants for whom the non-VR meditation was practiced in response to video playback on a standard 2D computer monitor, no differences were found in rated embarrassment between the VR and non-VR guided meditations, $t(40) < 1$, *ns*. Thus, it was only among participants for whom the non-VR meditation involved live face-to-face instruction that participants reported experiencing more embarrassment during the non-VR meditation than during the VR meditation, $t(40) = 2.26$, $p = .03$, $d' = .38$. To afford comparability with the findings reported for positive affect in Figs. 1, 2 displays results for all self-reported negative emotions also by meditation TYPE (VR vs. non-VR) as a main effect. Note, however, that negative affective responses were reported with far lower intensity than were positive emotions overall (the $y$-axis is five-fold smaller in Fig. 2 than it is in Fig. 1). Among the negative emotions rated, only embarrassment and stress stand out, being rated with an average above 1 on the 0–10 scale; all other negative emotions were rated near zero on average.

**Buddhist Affective States Scale** At the multivariate level, no main effects or interactions were found to be statistically significant, thus no univariate tests were conducted. Fig. 3 shows descriptively that some of the Buddhist affective states surveyed were experienced with moderate frequency independent of any clear difference between the VR and non-VR meditations, while others were experienced less saliently in response to both VR and non-VR meditations. For example, referring to observing, absorption, oneness, and insight, all four of these affective states were reported to be experienced by participants with means above 3 on the 0–10 scale, whereas other positive emotions such as "desire, wanting, craving" were experienced as less salient, approximating one on the 0–10 scale; negative states such as lethargy and confusion were also rated lower overall.

**Meditative Experiences Questionnaire** At the multivariate level, only the interaction between meditation TYPE (VR vs.

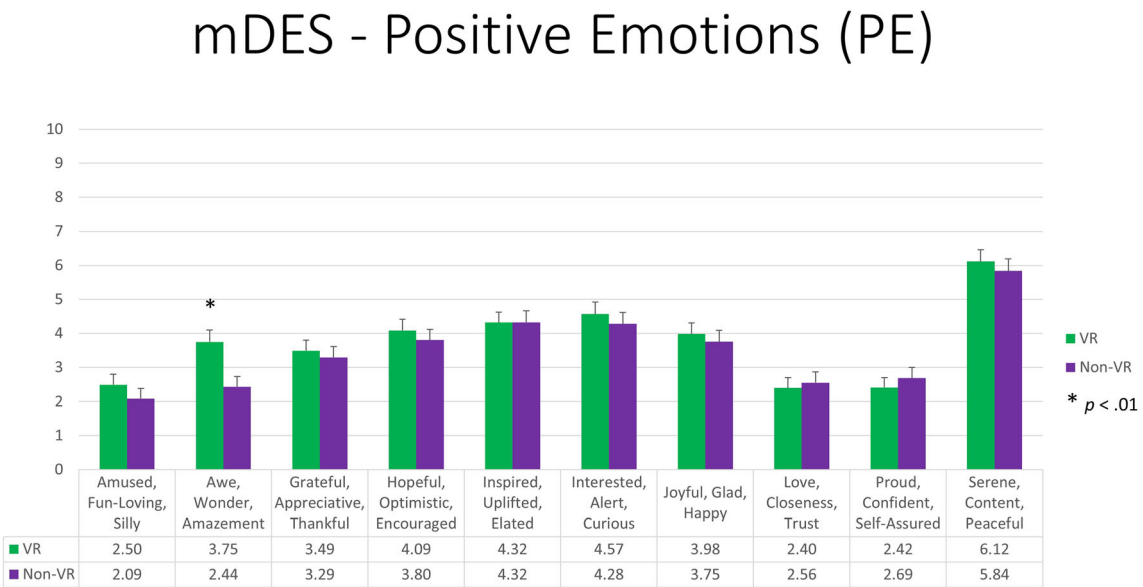



**Fig. 1** Results showing average response to 10 self-reported positive emotions in response to VR meditation (green) and non-VR meditation (purple). Errors bars depict standard error of measurement

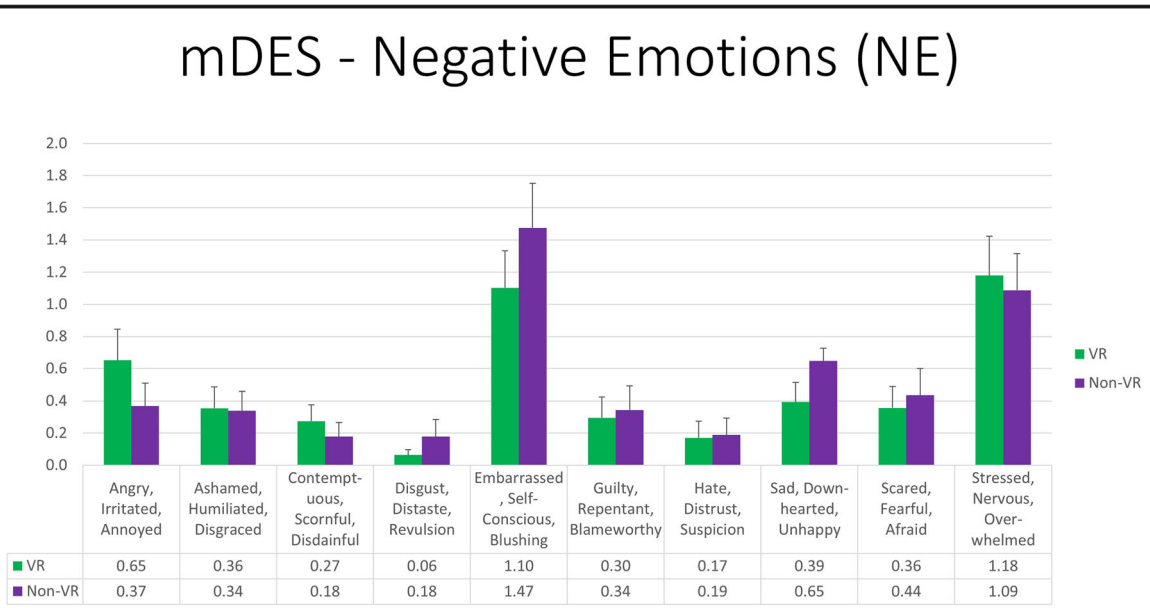



**Fig. 2** Results showing average response to 10 self-reported negative emotions in response to VR meditation (green) and non-VR meditation (purple). Errors bars depict standard error of measurement. Note the smaller scaling of the y-axis (0-2) as compared to the positive emotional responses illustrated in Fig. 1

non-VR) and the LIVE/VIDEO condition was found to be statistically significant ($\eta^2$-$p$ = .28) in reference to response to the MEQ. At the univariate level, this interaction was significant for only two of the 13 surveyed MEQ ratings, specifically "relaxed and calm" ($\eta^2$-$p$ = .06) and "fatigue, sleepiness" ($\eta^2$-$p$ = .09).

Following up the interaction with between-group $t$-tests showed that while no statistically significant differences were seen for the relaxation-calm ratings, the LIVE/VIDEO groups differed in self-reported fatigue-sleepiness only in response to the VR meditation, whereby the group who was given the live face-to-face instruction during the non-VR meditation reported more fatigue during the VR meditation than did the group who was given instruction by viewing video-taped instruction on a standard computer monitor; in other words, completing a guided meditation with live face-to-face instruction somehow increased the intensity of fatigue experienced during VR meditation; $t(80) = 2.20$, $p = .03$, $d = .46$.

Further, referring to within-group follow-up $t$-tests, we determined that, among the group who received instruction only by playback of a video on a standard computer monitor during

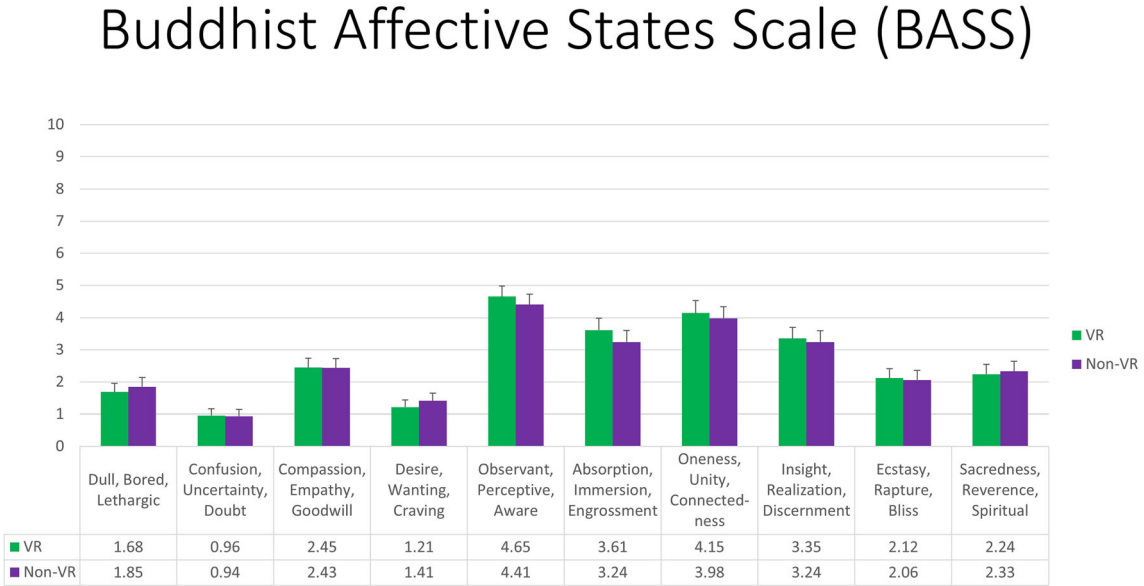



**Fig. 3** Results showing average response to 10 self-reported affective states frequently associated with Buddhist psychology in response to VR meditation (green) and non-VR meditation (purple). Errors bars depict standard error of measurement

the non-VR meditation, such participants reported feeling more relaxed and calm during the VR meditation, $t(40) = 2.31$, $p = .03$, $d' = .40$, and less fatigued-sleepy, $t(40) = 2.11$, $p = .04$, $d' = .39$. By comparison, within the group who received live face-to-face instructed meditation during the non-VR condition, no differences were statistically significant.

**Meditation Breath Attention Scores** At the multivariate level, the only statistically significant effect was the interaction between meditation TYPE (VR vs. non-VR) and the ORDER in which the VR vs. non-VR conditions were completed in ($\eta^2$-$p = .05$), which was thus followed up by *t*-tests between and within the ORDER groups. First, between-groups *t*-tests showed that the participants who received the VR meditation first tended to be more focused on their breath during the VR meditation than did participants who received the VR meditation second, $t(80) = 1.99$, $p < .05$, $d = .46$; comparably, no differences between the ORDER groups were seen in MBAS in response to the non-VR meditation, $t(80) < 1$. Second, in short, paired differences in MBAS scores between the VR and non-VR meditations within the groups who received each ORDER of the respective VR and non-VR meditations tended to show non-significant differences. Specifically, within the group who received the VR meditation first, no differences in MBAS were seen in response to the VR vs. non-VR meditation, $t(40) = 1.53$, $p = .13$. Similarly, within the group who received the VR meditation second, no differences in MBAS were seen in response to the two meditations, $t(40) = 1.30$, $p = .20$. Fig. 4 also shows results for MBAS compared as a main effect between the VR and non-VR conditions as the final pair of bar graphs.

**Satisfaction and Credibility Questionnaire** Finally, at the multivariate level, again, only the interaction between meditation TYPE (VR vs. non-VR) and the IV/2D condition was found to be statistically significant ($\eta^2$-$p = .28$). Interestingly, at the univariate level, the interaction was significant for 8 of the 10 surveyed satisfaction/credibility ratings that were surveyed, specifically: (1) "credible as a way to improve self-regulation and wellbeing" ($\eta^2$-$p = .06$), (2) "credible as an intervention for mental health problems including PTSD…" ($\eta^2$-$p = .07$), (3) "easy to complete" ($\eta^2$-$p = .13$), (4) "helpful" ($\eta^2$-$p = .08$), (5) "informative" ($\eta^2$-$p = .05$), (6) "calming" ($\eta^2$-$p = .07$), (7) "enjoyable" ($\eta^2$-$p = .14$), and (8) "would complete again" ($\eta^2$-$p = .10$).

Following up the interaction with between-group *t*-tests showed that the distinct IV/2D groups did not differ significantly in response to any of the satisfaction-credibility ratings whether referring to the VR or non-VR meditation. However, it was found that, among the group who received instruction in meditation via 2D video playback on a standard computer monitor during the non-VR condition, these participants rated the VR meditation, as compared to the non-VR meditation, to be more credible as an intervention for mental health problems, $t(40) = 2.80$, $p = .008$, $d' = .43$, easier to complete, $t(40) = 3.42$, $p = .001$, $d' = .42$, more helpful, $t(41) = 3.27$, $p = .002$, $d' = .45$, more informative, $t(40) = 2.15$, $p = .04$, $d' = .26$, more calming, $t(40) = 2.65$, $p = .012$, $d' = .48$, more enjoyable, $t(40)$

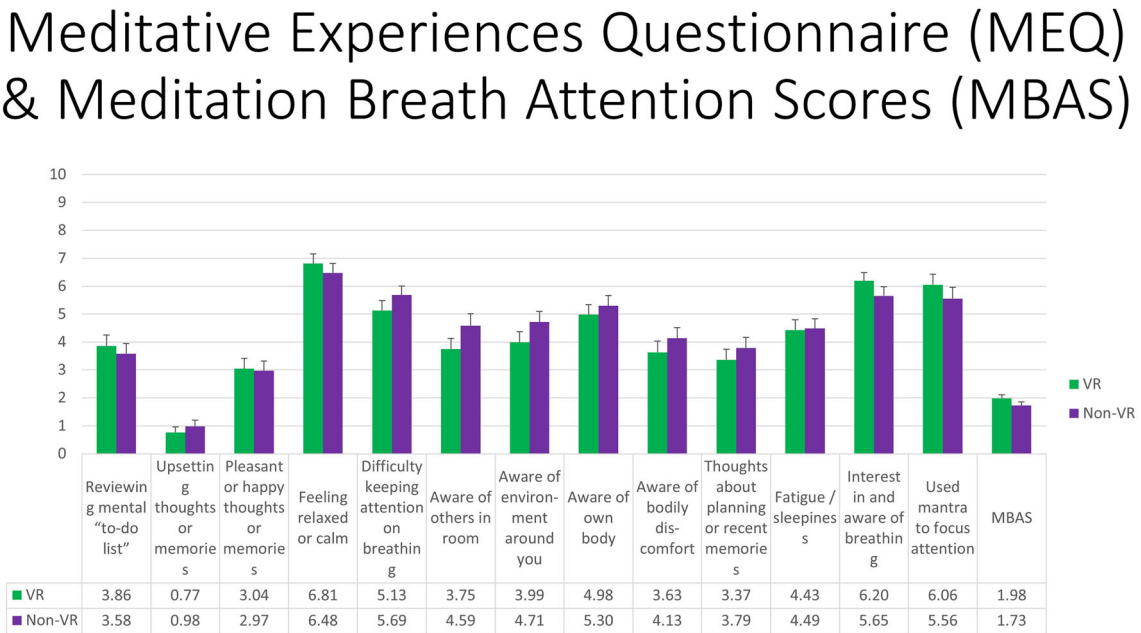



**Fig. 4** Results showing average response to 13 self-reported normative meditative experiences and for MBAS in response to VR meditation (green) and non-VR meditation (purple). Errors bars depict standard error of measurement. Note that while MEQ could range between 0-10, MBAS could range only between 0-3


**Fig. 5** Results showing average response to 10 satisfaction and credibility ratings in response to VR meditation (green) and non-VR meditation (purple). Errors bars depict standard error of measurement

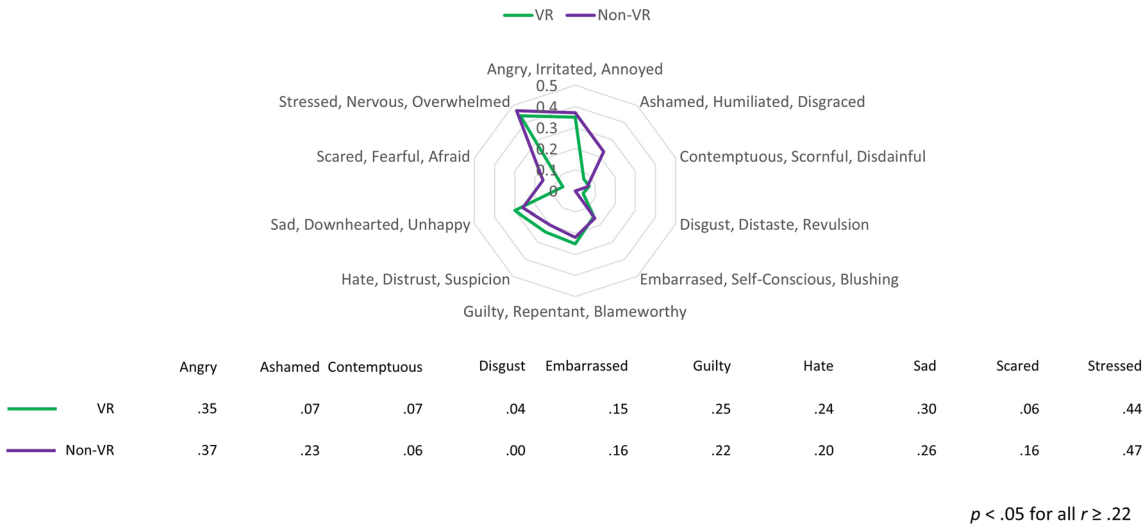
= 2.90, $p$ = .006, $d'$ = .55, and an activity that they would be more likely to complete again in the future, $t(40)$ = 2.67, $p$ = .01, $d'$ = .39. Comparably, among the group who received IV face-to-face instruction in guided meditation during the non-VR condition, no differences were found between the two meditations except for participants to report the VR meditation as overall slightly *less* enjoyable, $t(40)$ = 2.11, $p$ = .04, $d'$ = .33. Fig. 5 depicts results for the main effect comparing response between the VR and non-VR meditations.

**Thematic Analysis** The student researchers identified 34 non-overlapping themes within the open-ended responses, although only six met the a priori criteria for frequent and reliable observations (i.e., minimum 9 instances and twice the number of instances than disagreements). Only these six themes are therefore reported and submitted to further statistical analysis which were "calming/peaceful" ($n$ = 50), "preference" ($n$ = 33), "HMD uncomfortable" ($n$ = 23), "was difficult" ($n$ = 10), "virtual environment distracting" ($n$ = 9), and "sleepy/was comfortable/comforting/familiar" ($n$ = 9); six other themes were identified with an overall high frequency but disagreements between the student raters were too high to warrant further analysis, suggesting that instances of these themes are more difficult to identify reliably in participants' open-ended comments: "enjoyment," "comfortable," "facilitated focused attention," "distractibility," "immersive," and "awareness of physical surroundings."

Referring to an explicitly stated preference (or lack thereof) for one meditation format relative to the other, the comments of 33 participants were coded as such, of which only two explicitly indicated that they had no or equal preference for the VR vs. non-VR meditation. The remaining 31 participants were divided essentially evenly between those who indicated a preference for the VR meditation ($n$ = 15) and those preferring the non-VR meditation ($n$ = 16), with the majority of the latter group ($n$ = 12, 75%) receiving the live face-to-face meditation (i.e., only four participants who received the 2D flatscreen video meditation indicated they preferred it relative to the VR meditation). Note that observation of the "preference" code afforded post-hoc comparisons between the groups who preferred the VR vs. non-VR meditations on other measures such as response to the satisfaction-credibility scale, the results of which are shown in Supplementary Figure 1. Importantly, here, it can be seen that response to the VR meditation is essentially the same between participants who overall preferred the VR in comparison to those who overall preferred the live face-to-face meditation. In comparison, in response to the non-VR meditation, those who overall preferred the VR meditation regarded the non-VR meditation to be somewhat less credible as an intervention and to be less helpful, informative, calming, or enjoyable; they also reported being somewhat less likely to recommend it to a friend or complete it again themselves.

Referring to the other codes, unsurprisingly, all instances of the codes "HMD uncomfortable" and "virtual environment distracting" were observed with reference to the VR condition. Besides, none of the remaining codes were more significantly observed in response to the VR vs. non-VR meditation, or further as function of the ORDER or EYES conditions of the study.

**PTSD Symptoms as a Risk Factor for Distress in Response to Meditation** Correlations between individual differences in last-month PTSD symptoms and variability in negative




| | Angry | Ashamed | Contemptuous | Disgust | Embarrassed | Guilty | Hate | Sad | Scared | Stressed |
|---|---|---|---|---|---|---|---|---|---|---|
| VR | .35 | .07 | .07 | .04 | .15 | .25 | .24 | .30 | .06 | .44 |
| Non-VR | .37 | .23 | .06 | .00 | .16 | .22 | .20 | .26 | .16 | .47 |

$p < .05$ for all $r \geq .22$

**Fig. 6** Correlations between individual differences in last-month PTSD symptoms and variability in negative affective responses to the VR and non-VR meditations

affective responses to the VR and non-VR meditations are illustrated in Fig. 6. Higher last-month PTSD symptoms were associated with increased reports of feeling "angry," "guilty," "sadness," and "stressed" during the non-VR meditation. The same results were found in response to the VR meditation, in addition to a correlation with increased self-reported "hate" during the meditation.

Few significant correlations were observed associating last-month PTSD symptoms with other meditative experiences; please see an exploratory Table included as supplementary materials. In short, referring first to positive emotional responses, PTSD symptoms were associated with a *greater* experience of awe during the VR meditation, but less serene feelings during the non-VR meditation. Next, referring to other affective states described within Buddhist psychology, PTSD symptoms were associated lethargy (sloth-torpor)—as one of the four so-called hindrances—in response to both VR and non-VR meditations, as well as confusion (vicikicchā) as a second hindrance in response to non-VR meditation. Referring to satisfaction and perceived credibility, persons with greater PTSD symptoms reported less enjoyment in response to both meditations, and that the non-VR meditation was less calming. Finally, PTSD symptoms were also associated with several ratings to the MEQ in response to both meditations: increased "unpleasant or upsetting thoughts or memories," increased "thoughts about planning or recent memories," and decreased relaxation. Further, uniquely in response to the non-VR meditation, persons with increased PTSD symptoms reported greater mind wandering relating to "review of a mental to-do list," and a greater awareness of both the presence of others in the room and the external environment during the non-VR meditation; these may be indicative of a greater susceptibility to distraction accompanying PTSD uniquely in response to the non-VR meditation.

## Discussion

Previous research has revealed the promise of VR for inducing positive affect in response to guided meditation practices when conducted within pleasant computer graphical environments viewed through HMD (Frewen et al., 2020; Miller et al., 2021; Mistry et al., 2020; Navarro-Haro et al., 2017, 2019) and has also demonstrated the application of immersive 360° videos of similarly pleasant but real-world recorded environments for use in meditation practice also viewed through HMD (Bennett, 2018; Tarrant et al., 2018). However, as much as these prior demonstrations have facilitated immersive meditative experiences in various virtual settings, these previous meditations involved decidedly solitary activities; meditative instructors were not visually depicted within the scenes (c.f., Cikajlo et al., 2016, who used avatars). In effect, these activities were absent of any experience of the sangha, that is, the opportunity for a social experience in meditation practice among a community of practitioners and, most especially, in the presence of a trusted, compassionate, and competent meditation instructor or teacher. The present research was therefore conducted to evaluate response to VR vs. non-VR meditation while including the factor of social human presence through the inclusion of a meditation instructor, whether experienced *physically* (i.e., IV condition, face-to-face) or only *perceptually* (i.e., virtually, whether in a 2D or 3D visual

format). In either case, the guided meditation was composed of a relatively simple breath-focused meditation of only 5 min duration during which instruction further sought to adhere to the principles of trauma-informed care due to prior evidence suggesting that the presence of baseline PTSD symptoms represents a risk factor for experiencing distress during meditation (e.g., Zhu et al., 2019).

In comparing positive affective responses, we found that only a single positive emotional experience differed between the VR and non-VR meditations, specifically that of awe, thus partially supporting our hypothesis. Such results are consistent with the prior findings of Mistry et al. (2020) that showed that awe was the only positive emotional experience that was rated higher in response to VR meditation regardless of the order in which VR and non-VR meditations took place. Moreover, such results are consistent with much prior evidence validating VR as an effective, novel modality for provoking the experience of awe independent of meditation practice, and not simply due to the associated novelty of the technology itself (Chirico et al., 2016, 2017, 2018). We suspect that the benefits of VR for inducing awe are therefore unlikely to be unique to meditation practice but could be used to engage interest in introducing meditation to new or novice practitioners as well as in mental health applications (e.g., Navarro-Haro et al., 2017, 2019). Further, given the consistent demonstration of inducing awe using VR, future research should investigate potential longitudinal efficacies of this pattern.

Beyond the experience of awe, however, no other positive emotions or other affective states described within Buddhist psychology differed prominently between the VR-360° video (3D) and non-VR (2D) meditations in the current study. It is also, however, important to point out that overall participants reported experiencing only a moderate level of positive affect during both the VR and non-VR meditations, with no ratings except "serene, content, peaceful" having a mean greater than five on the 0–10 rating scale that was used. Although this differs from the stronger positive affective response to VR meditation that were recently described by Mistry et al. (2020), who used computer graphical virtual environments, the current results are more so consistent with the findings of Bennett (2018) and Tarrant et al. (2018) who did not observe significant differences in subjective emotional responses between VR vs. non-VR meditations when the VR meditations involved use of 360° videos. It is important to point out that, in contrast to the prior studies that depicted highly pleasant and provocative surroundings that are perhaps atypical to daily life for most persons (e.g., waterfall; oceanside; mountainous range), whether computer simulated or recorded using 360° videography, the current videos displayed a relatively neutral university office setting that was essentially identical to the one in which the participant was physically present during all aspects of the research procedure (see also, Cebolla et al., 2019). As a result, regardless of whether or not meditations were completed within VR, when participants looked around themselves, the experience was reported as highly similar, which is consistent with findings by Chirico et al. (2018) whereby virtual environments designed to invoke awe or neutral responses did so accordingly. For example, one participant commented: "It was weird to be placed in the same room…" when wearing the HMD.

Comparably, regarding negative affective responses, VR meditation was reported to differ with regard to perceived self-consciousness and embarrassment only when compared to live, face-to-face instruction (i.e., IV format). Here, meditating with an instructor face-to-face invoked greater reports of self-consciousness and embarrassment when compared with VR meditation. These findings suggest the intriguing possibility that giving meditation instruction via VR may offer a more comfortable alternative to traditional live face-to-face instruction for certain participants, potentially due to the alleviation of interpersonal anxieties and awkwardness associated with meditating especially in the social-physical presence of another person one-to-one, as opposed to in group format.

However, other subjective differences were found between VR and non-VR meditation when the non-VR meditation involved viewing of the same pre-recorded 360° meditation video on a standard laptop monitor (i.e., 2D format). Here, participants reported feeling more relaxed and calmer during the VR meditation while experiencing fewer difficulties maintaining their attention on their breathing or finding themselves becoming fatigued, as compared to practicing meditation via standard laptop screen. In this case, results suggest that the VR viewing conditions facilitated by wearing a HMD have some perceived benefits over the standard computer displays for evoking relaxation and focused attention toward breathing. These results could facilitate increased engagement in VR meditative practices, including when practical and healthcare conditions necessitate use of remote mediums to deliver mindfulness-based interventions including during the present quarantine period following COVID-19. Indeed, several participants reported being more able to focus their attention due to the inherent sensory restrictions and felt presence evoked by the immersive virtual environment of VR. For example, one participant, referring to the 3D (VR) meditation, as compared to the 2D meditation, reported: "[I was]… more encapsulated in that… " while another participant described: "I was immersed in it… there was nothing there to distract me. All I could do was meditate and focus on that…" while finally another participant remarked: "I liked it, it is kind of easier to focus when your senses are kind of closed off." Nevertheless, indications for improved meditative focus during VR vs. non-VR meditation as measured by MBAS were not statistically significant, and so such self-reports remain to be validated using objective measures of attentional performance. Although the VR meditation represented a novel introduction to meditation for all participants in this study, the majority tended to find it a credible approach to learning meditation. In fact, among participants who received the

computerized delivery of pre-recorded videos in both conditions, the 3D-VR format of delivery using the HMD, as compared to standard 2D-laptop viewing of the same videos, was rated as a more credible intervention for mental health problems, easier to complete, more helpful, more informative, more calming, and more enjoyable. Consequently, such participants indicated that they would also be more likely to practice meditation again in these conditions, when compared with the standard computerized displays. These findings seem highly relevant to consider in light of the current global viral pandemic and the consequent need for evidence-based virtual mediums for delivering mental health interventions in either case. Thus, VR experiences provided by means of pre-recorded 360° videos viewed via HMD would seem to present a viable alternative for accessing remote meditation instruction, which may prove advantageous in addressing barriers to face-to-face mental healthcare such as cost, transportation, and distance, and is especially relevant given the current need to control the spread of infectious disease via physical distancing (Rizzo & Shilling, 2017).

These points notwithstanding, among participants who received live face-to-face instruction instead of via standard laptop viewing, the VR meditation was rated as overall less enjoyable and more fatiguing. Further, approximately equal numbers of participants reported in open-ended comments that they preferred the VR and IV (face-to-face) conditions. These findings underscore the perceived unique merit of face-to-face practices for at least some practitioners. It seems likely that many meditators will ultimately continue to prefer the true physical rather than only virtual-perceptual presence of the sangha and meditation teacher.

Finally, despite our use of a trauma-informed care approach to the narration of the meditation instruction, we found that participants with elevated PTSD symptoms at baseline (pre-meditation) were still more likely to experience distress during the meditations, including indicators that participants experienced unpleasant and upsetting memory recall during the meditation (although it was not specifically assessed whether traumatic memory recall was re-experienced per se). Further consistent with the prior findings of Mistry et al. (2020), such distress was often experienced during both VR and non-VR meditations, albeit that certain associations appeared specific to the non-VR meditation. Overall, these findings underscore previous cautionary notes regarding the conduct of meditation practices with persons with PTSD symptoms so that such practices are not unduly upsetting to participants (Mistry et al., 2020; Zhu et al., 2019).

## Limitations and Future Research Directions

Although we believe the results of the current study are important, associated limitations are also important to acknowledge. In terms of generalizability, the study only included young, educated adults; therefore, our results may somehow be particular to that group. As a limitation shared with previous related studies, evaluation of these approaches in persons of other demographic characteristics is thus important. Beyond that, we recognize that our comparison between face-to-face meditation instruction and that delivered through the use of VR via HMD was confounded by the time in which the meditation instruction occurred. In other words, whereas face-to-face instruction occurred live, the video-based instruction provided through use of HMD and standard laptop viewing only involved a pre-recorded video playback. Although we sought to ensure comparability of these conditions by adhering to a common script for narration of the meditation, a stronger methodology would have entailed live streaming of the video instruction such that both guided meditations were based on instruction occurring in real time.

Furthermore, our virtual pre-recorded sessions took place in the same environment and physical proximity to the instructor, and we recognize that this represents a scenario of unlikely real-world application (c.f., Cebolla et al., 2019). In other words, it is more likely that virtual instruction would be provided to participants at home or remotely rather than also in the very same setting as face-to-face instruction. Although this choice maximized the internal validity of our experiment as it pertained to holding the context of physical setting constant, the expected utility of VR and non-VR computer applications to meditation instruction would rather seem to relate to their portability, facilitating physical distancing by obviating the need to attend meditation instruction in person. A future study should therefore evaluate the impact of actual remote or virtual delivery of meditation sessions by comparing VR (HMD; 3D) and non-VR (2D) formats. Finally, future research could also directly compare the impact of the two kinds of VR experiences described herein: computer graphics vs. 360° videography of similar virtual environments.

We conclude that, overall, providing scripted one-on-one instructor-present guided meditation practices virtually using 360° videos viewed via HMD represents a viable alternative to providing the same instruction face-to-face or via standard flatscreen (e.g., laptop) monitors. Participants considered this approach to be highly satisfactory and credible in application to interventions for trauma- and stressor-related disorders overall, and approximately half of the participants who explicitly voiced a preference for one or the other meditation format indicated a preference for the VR format. Moreover, meditating in the context of VR was associated with a heightened experience of awe overall. Further, when compared specifically with face-to-face live instruction in the traditional manner, VR meditation was reported to be less embarrassing, although it was also reported to be less enjoyable and more fatiguing by some individuals. In

contrast, when compared with viewing the same meditation on a standard flatscreen, which we regard to be the more relevant comparison in the current context of a global viral pandemic (wherein physical distancing is necessary and face-to-face instruction may simply not be a viable option for at least some time), on the basis of the present research, one can expect VR meditation to be associated with more relaxation, less distractibility away from breath sensation, and less fatigue. Further, assessed by reported attention to breathing at various intervals during the meditation, similar levels of attention were found in response to the VR and non-VR meditations, further suggestive of similarities between the experience of the two formats of practicing meditation. Nevertheless, cautionary notes regarding the risk for experiencing distress among persons with PTSD symptoms appear to continue to apply both in the case of VR and non-VR meditations.

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**Author Contribution** MW co-developed research stimuli (meditation scripts and recordings) under the supervision of PF, co-administered research procedure and co-collected data under the supervision of PF, co-analyzed data with PF, and wrote first draft of the paper as an accepted psychology honors thesis supervised by PF.

DM co-developed research stimuli (meditation scripts and recordings) under the supervision of PF, co-administered research procedure, co-collected data under the supervision of PF, and edited the paper.

RJ co-developed research procedure and edited the paper.

PF co-developed research stimuli (meditation scripts and recordings), supervised MW and DM in their administration of the research procedure and data collection, co-analyzed data with DM, and corresponding author of the revised manuscript.

## Declarations

**Ethics Statement** This research was approved by the research ethics board of Western University, Canada.

**Informed Consent Statement** All participants provided written informed consent prior to participating.

**Conflict of Interest** The authors declare no competing interests.

## References


Bennett, S. M. (2018). *A trip to the beach: experimental investigation of mood, the body, and presence in virtual reality meditation* (Publication No. 10829168) [Doctoral Dissertation, University of Oregon]. ProQuest Dissertations Publishing. https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/23804/Bennett_oregon_0171N_12235.pdf?sequence=1&isAllowed=y.

Blevins, C. A., Weathers, F. W., Davis, M. T., Witte, T. K., & Domino, J. L. (2015). The Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5): development and initial psychometric evaluation. *Journal of Trauma Stress., 28*(6), 489–498. https://doi.org/10.1002/jts.22059.

Bowen, S., & Kurz, A. S. (2011). Between-session practice and therapeutic alliance as predictors of mindfulness after mindfulness-based relapse prevention. *Journal of Clinical Psychology, 68*(3), 236–245. https://doi.org/10.1002/jclp.20855.

Boyatzis, R. E. (1998). *Transforming qualitative information: thematic analysis and code development*. Sage Publications, Inc.

Cebolla, A., Herrero, R., Ventura, S., Miragall, M., Bellosta-Batalla, M., Llorens, R., & Baños, R. M. (2019). Putting oneself in the body of others: a pilot study on the efficacy of an embodied virtual reality system to generate self-compassion. *Frontiers in Psychology, 10*, 1521. https://doi.org/10.3389/fpsyg.2019.01521.

Chirico, A., Yaden, D. B., Riva, G., & Gaggioli, A. (2016). The potential of virtual reality for the investigation of awe. *Frontiers in Psychology, 7*, 1766. https://doi.org/10.3389/fpsyg.2016.01766.

Chirico, A., Cipresso, P., Yaden, D., Biassoni, F., Riva, G., & Gaggioli, A. (2017). Effectiveness of immersive videos in inducing awe: an experimental study. *Scientific Reports, 7*(1). https://doi.org/10.1038/s41598-017-01242-0.

Chirico, A., Ferrise, F., Cordella, L., & Gaggioli, A. (2018). Designing awe in virtual reality: an experimental study. *Frontiers in Psychology, 8*, 2351. https://doi.org/10.3389/fpsyg.2017.02351.

Cikajlo, I., Čižman-Štaba, U., Vrhovac, S., Larkin, F., & Roddy, M. (2016). RECOVR: realising collaborative virtual reality for wellbeing and self-healing. *Proceedings of the Third IASTED International Conference of Telehealth and Assistive Technology (TAT 2016). October 6 - 7, 2016 Zurich, Switzerland.* https://doi.org/10.2316/P.2016.846-008

Devilly, G. J., & Borkovec, T. D. (2000). Psychometric properties of the credibility/expectancy questionnaire. *Journal of Behavior Therapy and Experimental Psychiatry, 31*(2), 73–86. https://doi.org/10.1016/S0005-7916(00)00012-4.

Felitti, V. J., Anda, R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., Koss, M. P., & Marks, J. S. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults. The Adverse Childhood Experiences (ACE) study. *American Journal of Preventative Medicine, 14*(4), 245–258. https://doi.org/10.1016/s0749-3797(98)00017-8.

Fredrickson, B. L., Tugade, M. M., Waugh, C. E., & Larkin, G. R. (2003). What good are positive emotions in crisis? A prospective study of resilience and emotions following the terrorist attacks on the United States on September 11th, 2001. *Journal of Personality and Social Psychology, 84*(2), 365–376. https://doi.org/10.1037/0022-3514.84.2.365.

Frewen, P. A., & Lanius, R. A. (2015). *Healing the traumatized self: consciousness, neuroscience, and treatment*. Norton Professional Books.

Frewen, P. A., Evans, E. M., Maraj, N., Dozois, D. J. A., & Partridge, K. (2008). Letting go: mindfulness and negative automatic thinking. *Cognitive Therapy and Research, 32*(6), 758–774. https://doi.org/10.1007/s10608-007-9142-1.

Frewen, P. A., Mackinley, J., Lundberg, E., & Wrath, A. J. (2011). Assessment of response to mindfulness meditation: meditation breath attention scores in association with subjective measures of state and trait mindfulness difficulty letting go of depressive cognition. *Mindfulness, 2*(4). https://doi.org/10.1007/is12671-011-0069-y.

Frewen, P., Rogers, N., Flodrowski, L., & Lanius, R. (2015). Mindfulness and metta-based trauma therapy (MMTT): initial development and proof-of-concept of an internet resource. *Mindfulness, 6*, 1322–1334. https://doi.org/10.1007/s12671-015-0402-y.

Frewen, P. A., Brown, M. F. D., & Lanius, R. A. (2017). Trauma-related altered states of consciousness (TRASC) in an online community sample: further support for the 4-D model of trauma-related

dissociation. *Psychology of Consciousness: Theory, Research and Practice, 4*(1), 92–114. https://doi.org/10.1037/cns0000091.

Frewen, P., Mistry, D., Zhu, J., Kielt, T., Wekerle, C., Lanius, R. A., & Jetly, R. (2020). Proof-of-concept of an eclectic, integrative therapeutic approach to mental health and well-being through virtual reality technology. *Frontiers in Psychology, 11*, 858. https://doi.org/10.3389/fpsyg.2020.00858.

Guest, G., MacQueen, K. M., & Namey, E. E. (2012). *Applied thematic analysis*. SAGE Publications, Inc. https://doi.org/10.4135/9781483384436.

Lauricella, S. (2014). Mindfulness meditation with undergraduates in face-to-face and digital practice: a formative analysis. *Mindfulness, 5*(6), 682–688. https://doi.org/10.1007/s12671-013-0222-x.

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. D. (2001). A cross-media presence questionnaire: the ITC sense of presence inventory. *Presence Teleoperators and Virtual Environments, 10*(3), 282–297. https://doi.org/10.1162/105474601300343612.

Miller, M., Mistry, D., Jetly, R., & Frewen, P. (2021). Meditating in virtual reality 2: phenomenology of vividness, egocentricity and absorption-immersion. *Mindfulness*. https://doi.org/10.1007/s12671-020-01589-y.

Mistry, D., Zhu, J., Tremblay, P., Wekerle, C., Lanius, R., Jetly, R., & Frewen, P. (2020). Meditating in virtual reality: proof-of-concept intervention for posttraumatic stress. *Psychological Trauma Theory Research Practice and Policy*. Advance online publication. https://doi.org/10.1037/tra0000959.

Navarro-Haro, M., López-del-Hoyo, Y., Campos, D., Linehan, M. M., Hoffman, H. G., García-Palacios, A., Modrego-Alarcon, M., & Borao, L.,& García-Campayo, J. (2017). Meditation experts try virtual reality mindfulness: a pilot study evaluation of the feasibility and acceptability of virtual reality to facilitate mindfulness practice in people attending a mindfulness conference. *PLoS One, 12*(11). https://doi.org/10.1371/journal.pone.0187777.

Navarro-Haro, M. V., Modrego-Alarcón, M., Hoffman, H. G., López-Montoyo, A., Navarro-Gil, M., Montero-Marin, J., García-Palacios, A., Borao, L., & García-Campayo, J. (2019). Evaluation of a mindfulness-based intervention with and without virtual reality dialectical behavior therapy mindfulness skills training for the treatment of generalized anxiety disorder in primary care: a pilot study. *Frontiers in Psychology, 10*, 55. https://doi.org/10.3389/fpsyg.2019.00055.

Peilot, B., Andrell, P., Samuelsson, A., Mannheimer, C., Frodi, A., & Sundler, A. J. (2014). Time to gain trust and change: experiences of attachment and mindfulness-based cognitive therapy among patients with chronic pain and psychiatric co-morbidity. *International Journal of Qualitative Studies on Health and Well-Being, 9*, 24420. https://doi.org/10.3402/qhw.v9.24420.

Riva, G., & Wiederhold, B. K. (2020). How cyberpsychology and virtual reality can help us to overcome the psychological burden of coronavirus. *Cyberpsychology, Behavior and Social Networking*, 277–279. https://doi.org/10.1089/cyber.2020.29183.gri.

Rizzo, A., & Shilling, R. (2017). Clinical virtual reality tools to advance the prevention, assessment, and treatment of PTSD. *European Journal of Psychotraumatology, 8*, 1414560. https://doi.org/10.1080/20008198.2017.1414560.

Sarason, I. G., Johnson, J. H., & Siegel, J. M. (1978). Assessing the impact of life changes: development of the Life Experiences Survey. *Journal of Consulting and Clinical Psychology, 46*(5), 932–946. https://doi.org/10.1037/0022-006X.46.5.932.

Schnurr, J. B., & Montgomery, G. H. (2010). A systematic review of therapeutic alliance, group cohesion, empathy, and goal consensus/collaboration in psychotherapeutic interventions in cancer: uncommon factors? *Clinical Psychology Review, 30*(2), 238–247. https://doi.org/10.1016/j.cpr.2009.11.005.

Solhaug, I., Eriksen, T. E., de Vibe, M., Haavind, H., Friborg, O., Sorlie, T., & Rosenvinge, J. H. (2016). Medical and psychology student's experiences in learning mindfulness: benefits, paradoxes, and pitfalls. *Mindfulness, 7*, 838–850. https://doi.org/10.1007/s12671-016-0521-0.

Tarrant, J., Viczko, J., & Cope, H. (2018). Virtual reality for anxiety reduction demonstrated by quantitative EEG: a pilot study. *Frontiers in Psychology, 9*, 1280. https://doi.org/10.3389/fpsyg.2018.01280.

Weathers, F. W., Litz, B. T., Keane, T. M., Palmieri, P. A., Marx, B. P., & Schnurr, P. P. (2013). *The PTSD checklist for DSM-5 (PCL-5) – LEC-5 and extended criterion A*. Scale available from the National Center for PTSD at https://www.ptsd.va.gov.

Williams, W., Graham, D. P., McCurry, K., Sanders, A., Eiseman, J., Chiu, P. H., & King-Casas, B. (2014). Group psychotherapy's impact on trust in veterans with PTSD: a pilot study. *Bulletin of the Menninger Clinic, 78*(4), 335–348. https://doi.org/10.1521/bumc.2014.78.4.335.

Zhu, J., Wekerle, C., Lanius, R., & Frewen, P. (2019). Trauma- and stressor-related history and symptoms predict distress experienced during a brief mindfulness meditation sitting: moving toward trauma-informed care in mindfulness-based therapy. *Mindfulness, 10*(10), 1985–1996. https://doi.org/10.1007/s12671-019-01173-z.