A preliminary study on the effectiveness of a Virtual Reality system to enhance Tonglen compassion practice

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Abstract

Compassion-based interventions have been shown to improve numerous mental health outcomes. However, they are time- and effort-intensive, and entail a high dropout rate. Virtual Reality (VR) could be a useful tool to enhance compassion practice by immersing users in a VR environment, thus facilitating the construction and sustainment of mental images necessary for the practice. The objective of this preliminary study is to describe the VR system and assess its capacity to successfully guide a complex compassion practice: Tonglen meditation (TM). 30 participants practiced TM for 15 minutes in a VR environment (Tonglen-VR). Assessment took place before and after TM evaluating self-reported, compassion, criticism, and affect. Moreover, heart rate variability was collected during the whole session as an objective indicator of compassion state. Results showed significantly higher levels of compassion and positive affect, coupled with a decrease in criticism and negative affect. Physiological markers showed a significant increase in heart-rate variability compared to baseline, indicating higher parasympathetic nervous system activation. Moreover, participants showed high engagement and level of compassion practice quality. This study provides preliminary evidence regarding the effectiveness of a Tonglen-VR system as a promising tool in improving practice of compassion.

1. Introduction

1.1 Compassion and Compassion-Based Interventions

Compassion has been defined as a cognitive, affective, and behavioral process which involves recognizing suffering, understanding its universality, empathizing with the person in distress, tolerating uncomfortable feelings, and being motivated to alleviate its suffering (Strauss et al., 2016). The importance of compassion is acknowledged in numerous sectors of our society and research in this field is continuously growing (Strauss et al., 2016). Currently, there are several Compassion-Based Interventions (CBIs) that are designed to foster well-being and social relationships, such as Compassion-focused therapy (Gilbert, 2014), Cognitively-Based Compassion Training (Ash et al., 2021), Compassion Cultivation Training (Goldin & Jazaieri, 2017), and others. Randomized controlled trials have demonstrated the effectiveness of CBIs as promising tools in improving empathy and compassion toward oneself and others (Brito-Pons et al., 2018), as well as in reducing distress, self-criticism, anxiety, and depressive symptoms (Kirby et al., 2017a).

The meditation practices in CBIs belong to the family of constructive meditations' where individuals intentionally cultivate compassionate thoughts and feelings to enhance their compassion skills, relying on mental imagery abilities (Dahl et al., 2015). A common meditation practice within several CBIs is Tonglen meditation (TM; Goldin & Jazaieri, 2017). Tonglen, which means taking and giving, is a visualization practice that encourages practitioners to confront others' suffering while reducing self-centeredness, thus nurturing compassion (Drolma, 2019). More specifically, this practice involves compassionately visualizing a person in pain, taking in its suffering, transforming it within oneself, and then offering back happiness and well-being (Drolma, 2019). Traditionally, this meditation is combined

with controlled breathing techniques. During inhalation, practitioners imagine taking in the pain and suffering from another, visualized as streams of dark clouds, while on exhaling, they imagine sending out happiness and good fortune to the other, represented as fresh air and white clouds (Drolma, 2019). Despite its potential benefits, empirical research on TM's effects remains limited (Mcknight, 2012; Pagliaro et al., 2016; Pardy et al., 2016). Furthermore, although CBIs have the potential to improve numerous mental health outcomes, not all individuals who are encouraged to practice compassion observe clear benefits (Gilbert & Mascaro, 2017), since the meditation practice itself is time- and effort-intensive and entails a high dropout rate (Nam & Toneatto, 2016). Indeed, meditation practice often involves years of daily commitment to be considered a long-term meditator (e.g., Kral et al., 2018). In the context of secular interventions, validated CBIs typically take the format of 8-week programs with weekly sessions lasting 2 hours, a commitment to 45 minutes of daily practice, and a one-day silent retreat (e.g., Goldin & Jazaieri, 2017; Neff & Germer, 2013). However, when participants are given the freedom to choose outside a structured program, there is considerable variation in the time spent practicing compassion (Leaviss & Uttley, 2015). This can result in dropout rates that vary across studies (e.g., between 10% (e.g., Asano et al., 2022) and 36% (e.g., Grodin et al., 2019) and are heavily context-dependent (Leaviss & Uttley, 2015). Moreover, the time and duration of the required commitment are often cited as possible reasons for non-completion of meditation practice (e.g., Galante et al., 2014).

1.2 Mental Imagery

One of the main identified obstacles associated with compassion practices involves the difficulties in mental imagery skills (Cebolla et al., 2019; Wilson-Mendenhall et al., 2023). Compassion meditation, which belongs to the family of constructive meditations, involves various mental imagery skills, encompassing creation, maintenance, examination, and alteration of mental images, each potentially influencing distinct cognitive processes (Pearson et al., 2013). It has been suggested that mental imagery not only has a powerful influence on emotions(Andreu et al., 2022; Holmes & Mathews, 2005) but is also an inherent aspect of human compassion (Gilbert, 2009).

Nonetheless, the vividness of imagined experiences can vary between individuals, and some may encounter difficulties in constructing and immersing themselves in imagined scenarios (Borst & Kosslyn, 2010; Pearson et al., 2013; Pearson, 2019). This inability can lead people to struggle to maintain mental imagery during compassionate meditation practices. Moreover, the absence of specific training to create, sustain, inspect or transform mental images, can hinder their ability to evoke feelings of compassion (Cebolla et al., 2019). This could decrease participants' motivation to continue the training necessary to develop compassion-based skills and positive attributes, thus negatively impacting the overall quality of the practice (Andreu et al., 2022).

Moreover, among compassion practices, TM is considered one of the most complex, because it requires stable attention and advanced mental imagery skills (Braun & Quaglia, 2022). Therefore, given the crucial role of mental imagery skills in TM, virtual reality (VR) could be a valuable tool to address this limitation since it facilitates the construction, maintenance, inspection, and transformation of mental images.

1.3 Tonglen-VR Meditation

VR has been proposed as an advanced imagery system that is highly effective at enhancing emotional, cognitive, and behavioral responses similar to real-life experiences (Day et al., 2004). VR technology creates computer-generated three-dimensional environments that offer the ability to transport users virtually, enabling them to actively explore and experience the video from any angle (Hamad & Jia, 2022). Indeed, users can engage with the virtual environment, and this environment in turn responds to the user's actions in real time. This approach provides a strong sense of immersion within the virtual environment (Riva et al., 2019; Slater & Usoh, 1994). Immersive VR has been identified as a potentially revolutionary tool for psychological intervention (Geraets et al., 2021). However, research in the area of VR as applied to compassion practice is still in its infancy. There are only a few studies showing promising results in using VR to improve self-compassion, compassion, and decreasing self-criticism (Cebolla et al., 2019; Falconer et al., 2016; Halim, 2023; Hidding et al., 2024; Žilinský & Halamová, 2023). Specifically, Cebolla and colleagues (2019) showed the effectiveness of self-compassion meditation supported by an embodied VR system in impacting positive and negative qualities toward oneself and others (Cebolla et al., 2019). Falconer and colleagues' study (2014) demonstrated that immersive virtual reality can promote positive emotions that are crucial for mental well-being while simultaneously reducing negative emotions such as fear (Falconer et al., 2014). The same research group showed that self-identification with virtual bodies within a virtual reality environment led to a significant reduction in symptoms of depression and self-criticism, as well as increased self-compassion (Falconer et al., 2016). Although these results seem promising, only a few studies have focused on compassion towards others (Brown et al., 2020; Falconer et al., 2014). Moreover, no study so far specifically explored whether TM effects can be enhanced through a VR system facilitating the complex mental imagery skills this practice requires.

1.4 The Present Study

Considering the aforementioned gaps, we developed and tested a VR-based system to practice TM within an immersive environment. By utilizing VR technology, we aimed to enhance participants' imagery skills and to reduce the effort in using mental imagery, thereby enhancing their ability in imagery processing and, in turn, to effectively engage in TM.

The aim of this study is to describe the development of the system and to provide preliminary data about the effectiveness of this Tonglen-VR meditation. Participants engaged in a Tonglen-VR meditation session while undergoing electrocardiogram (ECG) measurements. Self-report questionnaires assessing compassion, criticism, valence, and arousal were administered before and after the practice. We expected that the meditation practice would lead to an increase in positive affect, compassion levels, as well as decreased negative affect, and criticism toward others. Additionally, we expected that meditation practice would lead to improved heart rate variability (HRV), which can be interpreted as a biological outcome of compassion training. Moreover, we expected that participants would report high compassion practice quality and engagement during the Tonglen-VR meditation.

2. Methods

2.1 Participants

A total of 30 volunteers (*M* (age) = 30.73, age range = 18–57; *SD* (age) = 10.67; Male = 19, Female = 11) were recruited by advertisements at the University of Valencia (Spain). Inclusion criteria were being over 18 years old and proficient in Spanish. Exclusion criteria were a diagnosis of heart conditions, current mental health disorder, prior diagnosis of post-traumatic stress disorder, and the use of sedative or psychoactive medication that might alter collection of psychological data. Only 10 out of 30 participants had meditation experience. Within this group, 4 people practiced meditation regularly (between 3–7 times a week). Since the sample was from the general population no deficiencies in mental imagery skills were expected.

This preliminary study is part of a preregistered study on Open Science Framework *(link deleted to make the manuscript blinded)* and has been approved by the Ethics Committee of the University … (*detail deleted to make the manuscript blinded)* (*registration number: XXX*). The informed consent was signed by all participants. All the activities conducted in studies involving human participants adhered to the principles outlined in the 1964 Helsinki Declaration and its subsequent revisions or adhered to equivalent ethical standards.

2.2 Tonglen-VR System

Tonglen-VR consisted of the following three phases: (1) avatar personalization; (2) breathing exercises monitored by the system; (3) the Tonglen meditation (TM) phase. The proposed VR-system sought to give users a strong sense of immersion and isolation within the virtual environment, allowing them to focus on their senses during the practice. A video as an example of the Tonglen- VR session is provided in the **supplementary material**. In phase 1, participants created a personalized avatar for themselves and for their meditation partner. These avatars were customizable in terms of gender, hairstyle, clothing, face shape, and colors. In this phase, users could customize the environment to match their physical characteristics, thus promoting the integration of their bodies into the developed virtual context. Moreover, the avatar's movement was directly driven by the user's head movement, with positional and rotational tracking of the user's headset translating to corresponding adjustments in the avatar's orientation and position within the virtual environment.

Subsequently, in phase 2, participants performed a breathing exercise monitored by Tonglen-VR. They were asked to press the joystick controller up when inhaling and down when exhaling, in order to synchronize their breathing with the VR-system, ensuring it would be an ergonomic process. This training phase aimed at facilitating the users' incorporation into the practice and the familiarization with the synchronization of movements and breathing.

In phase 3, the Tonglen meditation phase began. This phase consisted of three steps. First, the environment was changed to a virtual forest, where participants could observe their avatar in a mirror to

enhance the sense of embodiment. This phase started with a five minutes of focused breathing meditation to ground the participants and prepare for the Tonglen meditation (step 1). Throughout the breathing meditation, participants continued to move the controller, with each inhalation (Fig. 1A) and exhalation (Fig. 1B). This integration of movement and breathing aimed to deepen the participants' connection to their breath and facilitate the transition into Tonglen meditation. During this practice, the participants observed light blue smoke representing cold air entering their virtual avatar during each inhalation. Conversely, during each exhalation, participants observed orange smoke leaving their avatar, symbolizing warmer air due to contact with the heart. This heart contact was represented by a light on the chest of the participant's avatar, which was visible when they gazed into the mirror. After this five-minute breathing meditation, the TM began (step 2). At this point participants could directly observe the avatar surrounded by a cloud of dark smoke representing their suffering and showing gestures of pain. By moving the controller with each breath, the participant inhaled some of that dark smoke (Fig. 2A) and exhaled clear smoke (Fig. 2B) representing relief from suffering, as is typically practiced in a standard TM. Participants continued for approximately five minutes, during which the dark cloud progressively turned into a lighter cloud until the end of the practice, when the avatar is liberated from suffering. The participants concluded with five minutes of breathing practice (step 3) without the presence of smoke nor any manipulation of the joystick, allowing the participant to focus solely on their breathing, and exit the meditation.

2.2.1 Technical Characteristics of Tonglen-VR system

Tonglen-VR was developed using the Unity game engine (*version 2021.3.16f1*), as part of the Unity Real-Time Development Platform, with scripts in C# and plugins for the Virtual Reality functionality (XR Plugin Management/XR Interaction Toolkit) (Unity, n.d.). Visualization was carried out using the Meta Oculus Quest 2 VR goggles (Meta Quest 2, Meta, n.d.), and the Meta controllers (Meta Quest 2 Controllers, Meta, n.d.) included with the headsets were used for breath control and user interactions. A computer connected to VR goggles was used to visualize the environment, with a screen resolution of 1832x1920 per eye and a horizontal Field of View (FOV) of 89º and a vertical FOV of 93º. Thus, allowing the researcher to monitor activity in real time during the execution. The interpupillary distance could be adjusted according to the user's individual needs. The user interface was developed using Unity tools and designed with Photoshop. It included an access menu, options to customize avatars, and a text tutorial.

2.3 Instruments

Self-report questionnaires and physiological measures were used to assess both participants' emotional responses (compassion, criticism, positive and negative affect), and VR environment judgment.

2.3.1 Questionnaires

The Hedonic and Arousal Affect Scale (HAAS, Roca et al., 2023). It is a validated questionnaire composed by 12 items expressed as words (e.g., calmed, irritable) to assess affective states, related to the degree of valence (positive or negative) and arousal (high or low) on a 5-point Linkert scale (0 = not at all; 4 = extremely). The original version (in Spanish) had good consistency of ω = 0.71 to 0.83. The total score is composed of four sub-scales (positive high arousal; positive low arousal; negative high arousal; and negative low arousal) and can range between 0 and 12.

Ad-hoc Visual Analog Scale of compassion and criticism (VAS; adapted from Falconer et al., 2015). It is an adaptation of the Self-Compassion and Self-Criticism Scale (SCCS) that measures compassion and criticism toward the self, using specific words such as hash, critical, kind, warm. Participants respond on a 7-point Likert scale (1 = not at all; 7 = very much). The original version showed good internal consistency, having a Cronbach's alpha of 0.91 for self-compassion and 0.87 for self-criticism. The adaptation consisted of translating the compassion and criticism-related words to Spanish and adapting them to compassion and criticism toward others. In total the scale consisted of four single items measuring compassion for others (i.e., kind, warm, connected, reassuring), and four single items measuring criticism toward others (critical, distant, cold, disapproving) with the total score per sub-scale ranging between 4 and 28.

The Presence and Reality Judgment in virtual environments (PRJ; Baños et al., 2000). This validated scale in Spanish assesses the experience of using VR on three sub-scale: reality judgment (8 items), internal/external correspondence (6 items), and attention/absorption (4 items) on a 10-point Likert scale (1 = not at all; 10 = absolutely). The original version showed good internal consistency (α = 0.82). The total score for each subscale could range from 1 to 10 for each subscale. This questionnaire was only completed after the VR experience.

The Compassion Practice Quality Scale (CPQS; Navarrete et al., 2021). This originally validated questionnaire in Spanish contains 12 items assessing compassion practice quality on a scale ranging from 0 (not at all) to 100 (totally). The scale, has a two-factor structure (that is, mental imagery and somatic perception), and scores are obtained by calculating the mean of the items. Participants indicate what percentage of the time their experience reflects each statement (for example, ‘During the practice, I had a lot of difficulty constructing the mental image that I was using to generate a state of compassion/self-compassion for the imagery factor and during the practice’, ‘I noticed feelings of warmth and nurturance in my body for the somatic perception factor’). The imagery factor includes items to assess the generation, maintenance, inspection and manipulation of the mental image used during the CBM. The somatic perception factor includes items to assess the perception of somatosensory components of the experience of compassion, such as warmth, comfort, and affection. Higher scores indicate greater quality of compassion practice. The questionnaire shows very good reliability in each subscale (Cronbach’s α = 0.91 for mental imagery and α = 0.89 for somatic perception, respectively). The total score for each subscale can range between 0 and 100. This questionnaire was only completed after the VR experience.

2.3.2 HRV

Several physiological studies have shown that HRV can be used as a primary outcome measure of compassion meditation training (Kirby et al., 2017b). The HRV (that is, the variation in the time intervals between heartbeats) was measured by using the root mean square of successive differences (RMSSD), which is considered a primary index of vagally-mediated HRV and is associated with better cardiovascular health and improved resilience to stress (Di Bello et al., 2020).

In this study, the RMSSD-HRV was measured using an ECG that was recorded with a Biopac MP160 using Ag/AgCl electrodes placed under the clavicles and on the first left lower rib at a sampling rate of 200 Hz. ECG recordings were collected using iMotions software v.10 (iMotions A/S, 2022), which was also used for the analysis. Heart rate data were first checked manually for artifacts (electrode noise, movement, and extraordinary peaks) offline before being subjected to a HRV analysis with iMotions. Data were filtered with a bandpass filter with a low cutoff frequency fixed at 5 Hz and a high cutoff frequency fixed at 15 Hz and the RMSSD was calculated. Both heart rate and RMSSD are reported as results.

2.4 Procedure

All participants attended individual sessions in the laboratory. Each session lasted approximately 45 minutes and comprised the following steps:

1. Baseline measurement, T1: Questionnaires
2. 15-minutes Tonglen-VR meditation
3. Post-experience measurement, T2: Questionnaires

Prior to the experiment, participants were instructed to refrain from smoking, consuming caffeine or engaging in exercise for at least two hours before. Upon arrival on the testing day, participants were briefed on the experimental procedures and given a consent form. Subsequently, they completed an initial online set of questionnaires (T1). Following this, the ECG was installed to record their heart rate for five minutes in a resting state with eyes open. Participants were instructed as follows: “Rest your hands on your legs, palms facing down. Keep your eyes open or half-open, but do not close them. Don’t talk during the measurement. You don’t have to think or do anything special.”

After the baseline measurement, participants engaged in Tonglen-VR experience. The headset was adjusted to the participants’ necessities and the VR-system was started. The participants’ cardiac activity was recorded during the entire experience. However, for data analysis, only the five minutes that the Tonglen phase (phase 2 of the meditation) lasted were considered. After the Tonglen-VR experience, the headset was removed, all the questionnaires were filled out for a second time (T2) and the ECG device was removed from the participant.

2.5 Data Analyses

All analyses were conducted using the statistical software R, version 4.3.2 (www.R-project.org*).* For all analyses, uncorrected two-tailed p-values are reported and were deemed statistically significant at <

0.05. A paired t-test was performed to compare the levels of our variable of interest (compassion, criticism, positive and negative affect) before and after the VR session and the HRV during the entire session.

3. Results

3.1 Questionnaire Analysis

Results (see Table 1) revealed a significant increase in compassion from time 1 (M = 19.90, SD = 4.03) to time 2 (M = 21.87, SD = 4.06); t (29) = -3.04, p = **0.005**), while criticism decreased significantly from time 1 (M = 10.20, SD = 3.61) to time 2 (M = 8.57, SD = 3.24), t (29) = 3.09, p = **0.004**). Furthermore, results showed a significant decrease of both negative valence-high arousal affect (time 1, M = 2.27, SD = 2.26; time 2, M = 0.67, SD = 1.06; t (29) = 4.18, p < **0.001**) and negative valence-low arousal affect (time 1, M = 2.47, SD = 1.85; time 2, M = 1.67, SD = 1.49; t (29) = 2.77, p = **0.01**).

While positive valence-low arousal affect significantly increased from time 1 (M = 7.90, SD = 1.95) to time 2 (M = 8.77, SD = 1.89); t (29) = -2.83, p = **0.008**), positive valence-high arousal affect did not statically change (t (29) = 0.94, p = 0.35).

3.2 Heart Rate Analysis

Results (see Table 1) showed a significant decrease of heart rate, measured by beats per minute (bpm), from time 1 (M = 76.44, SD = 12.23) to time 2 (M = 74.43, SD = 10.28), t (29) = 2.73, p = **0.01**). Furthermore, RMSSD, measured by milliseconds (ms), increased significantly from time 1 (M = 34.77, SD = 18.08) to time 2 (M = 45.98, SD = 20.10); t (29) = -5.69, p < **0.001**).

Table 1
Means, standard deviations, and paired-sample t-tests for main outcomes.

	Time 1 *Mean (SD)*	Time 2 *Mean (SD)*	*t* *(df = 29)*	*p*	Cohen's *d*
Compassion	19.90 (4.03)	21.87 (4.06)	-3.04**	0.005	0.49
Criticism	10.20 (3.61)	8.57 (3.24)	3.09**	0.004	-0.48
Neg valence-high arousal	2.27 (2.26)	0.67 (1.06)	4.18***	< 0.001	-0.66
Neg valence-low arousal	2.47 (1.85)	1.67 (1.49)	2.77**	0.01	-0.48
Pos valence-high arousal	8.17 (2.13)	7.93 (2.12)	0.94	0.35	-0.11
Pos valence-low arousal	7.90 (1.95)	8.77 (1.89)	-2.83**	0.008	0.45
Heart rate (bpm)	76.44 (12.23)	74.43 (10.28)	2.73**	0.01	-0.18
RMSSD (ms)	34.77 (18.08)	45.98 (20.10)	-5.69***	< 0.001	0.59

*Note. Pos, positive; Neg, negative; RMSSD, root mean square of successive differences. * p < .05; ** p < .01; ***p < .001.*

3.3 Quality of the Practice

Since the score of this questionnaire can range from 0 to 100 on each sub-scale, we can assume that between 0 and 30 the score is low; from 31 to 60 medium; and from 61 to 100 is high. The results therefore showed high scores on the subscale of mental imagery (*M* = 80.04, range = 33–100, *SD* = 16.28) indicating that participants had a high ability to create, inspect, sustain, and transform a vivid mental imagery during the meditation and low difficulties with imagination. Regarding the somatosensory subscale, the mean score of 66.35 (range = 17.5–100, *SD* = 21.72) indicates a relatively high level of somatic perception of feelings of warmth and connection during the TM.

3.4 Presence and Reality Judgment

Since the score of this questionnaire can range from 1 to 10, we can assume that between 1–3 the score is low; from 3.1–6.0 medium; and from 6.1–10 is high. Therefore, the results assessing the various aspects of the Tonglen-VR experience showed that the mean score for reality judgment was 5.84 (range = 2.62–10, SD = 1.76), indicating a moderate attribution to reality in the VR environment. Furthermore, participants reported relatively high levels of internal and external correspondence, with a mean score of 6.59 (range = 1.33–10, *SD* = 1.86), suggesting that the VR experience aligned well with their expectations and perceptions of the real world. Moreover, participants' mean attention and absorption score was 6.77 (range = 4.40–9.80, *SD* = 1.20), indicating a relatively high degree of immersion and engagement.

Discussion

To the best of our knowledge, this preliminary study is the first to develop and assess a VR system specifically designed for Tonglen Meditation, a complex compassion meditation. Our findings indicate a significant increase in compassion towards others, as well as reductions in levels of criticism following Tonglen-VR meditation practice. Similarly, participants' negative affect decreased, and was coupled with an increase in positive affect. The results also show that the Tonglen-VR increased HRV, which can be interpreted as an improvement in the primary biological outcome of compassion training (Kirby et al., 2017b). Indeed, our results show a significant increase in HRV during the Tonglen-VR meditation, compared to baseline. Taken together, the data support the use of VR as an effective tool for compassion practice, especially among individuals without prior experience of meditation.

Our results are in line with other studies, showing the effectiveness of VR-based compassion meditation in increasing compassion levels (Brown et al., 2020; Falconer et al., 2014) and in decreasing criticism levels (Žilinský & Halamová, 2023). Previous studies showed medium-to-large effect sizes for self-compassion, compassion, and self-criticism, with the use of VR several times. Our results showed medium effect sizes for compassion, criticism and affect questionnaires, using VR for a single session. Moreover, we found that performing TM within the VR-system yielded high levels of compassion practice quality, especially in the imagery domain. This suggests that participants showed high imagery skills while participating and few difficulties with mental images (around 80 out of 100) together with normal-to-high levels of warmth and connectedness with others (around 60 out of 100). Taken together, our results indicate that a single meditation performed in Tonglen-VR produces similar levels of compassion practice quality as compared to those achieved after 8 weeks of practice with the Compassion Cultivation Training program without technological support (Andreu et al., 2022). Although the short-term effect of one laboratory session and the long-term effects of presential compassion intervention are not directly comparable, these results nevertheless offer promising insights for future studies.

Given that compassionate feelings can be challenging for some participants due to the imagery skills required (Holmes & Mathews, 2005), it could be that experiences facilitated by immersive VR may help overcome this difficulty. One previous study showed that participants with more difficulties in imagery benefit more from VR (Cebolla et al., 2019). Having fewer difficulties with meditation may, in turn, increase adherence and motivation to practice. Indeed, as confirmed by other studies, VR exposure could increase treatment adherence(Botella et al., 2013; Gebara et al., 2016; Gregg & Tarrier, 2007; Navarro-Haro et al., 2017) and motivation (Gilbert, 2015).

Moreover, as other studies have demonstrated, mental imagery also has a powerful influence on emotions. Indeed, our study demonstrated a significant reduction in negative valence affect with both high and low arousal and an increase in positive valence affect with low arousal levels, but not high arousal. This finding suggests that participants experienced a shift towards more positive emotional states characterized by calmness, contentment, and peacefulness, but not excitement and happiness. Such changes in emotional valence align with the goals of compassion meditation, which aims to cultivate feelings of kindness, empathy, and well-being (Strauss et al., 2016). This result further supports

the potential therapeutic benefits of compassion meditation in enhancing emotion regulation and promoting overall psychological well-being.

Regarding physiological measurements, our study found an increase in HRV with a medium effect size, which is consistent with previous research showing increases after compassion meditation training (for example, Di Bello et al., 2020). Indeed, a recent review suggested that HRV may serve as a primary outcome measure for assessing the effectiveness of compassion meditation training in psychological terms (Kirby et al., 2017b). This alignment suggests that the changes observed in HRV in our study may reflect positive adaptations in autonomic nervous system function associated with the practice of compassion meditation. Additionally, the increase in HRV is consistent with the increase shown in positive valence-low arousal emotional level, due to the activation of the parasympathetic nervous system and thereafter feelings such as calmness and contentment promoted by compassion meditation (Naismith et al., 2023). These results suggest that practicing meditation in the Tonglen-VR system had a positive impact in promoting emotional and psychological well-being.

Finally, our results showed that performing TM within the VR system yields moderate levels of attribution to reality and high levels of internal and external correspondence together with high attention and absorption, which suggests a high degree of immersion and engagement during the VR experience. Given the characteristics of Tonglen-VR, it was not expected that a high attribution of reality would be generated, particularly in the TM phase and the interaction with the smoke (which does not resemble a real-life activity). However, a high degree of internal and external correspondence was expected, which shows that the interaction within the environment was well achieved. Indeed, our VR system is aligned what Gaggioli defines as a “transformative digital experience” (Gaggioli, 2016): a synthetic and controlled experience that does not have a purpose to recreate reality, but which can promote personal development and epistemic expansion through embodying other than the known self and/or environments.

Overall, this study suggests that the practice of TM supported by a VR-system has a great potential for compassion practice. However, the results must be understood within the context of the study’s limitations. First, this preliminary study should be confirmed with a larger sample. Further research is needed to explore additional measures related to the assessment of the Tonglen-VR system and the overall experience. For example, the use of interviews or open-ended questionnaires could provide useful information about participants’ experience in the environment or phenomenological methods (Petitmengin et al., 2019) to understand how the VR helped the participants to gain more compassion. Moreover, the adaptation of self-compassion and self-criticism scale (Falconer et al., 2015) to measure compassion and criticism to others in this study should also be acknowledged as a limitation. While this measure was used to efficiently capture specific aspects of the participants' experiences, they may lack the robustness of validated multi-item scale. Future studies should incorporate well-validated tools that allow measuring compassion and criticism state to enhance the reliability and generalizability of the findings. Finally, a comparative study with a control group where no VR is used would help understanding of how the VR environment adds value to the practice of meditation.

Although VR has potential applications in compassion practice, the field is still in its infancy. Indeed, there is currently very little research confirming the effectiveness of VR in enhancing prosocial behavior (Sora-Domenjo, 2022). More rigorous studies are needed to validate existing data, particularly regarding the long-term effects of VR use (Sora-Domenjo, 2022). It is possible that the enhancing effects of VR might make it more difficult to practice compassion without technological support over the long term. Additionally, since compassion involves motivation and commitment to embodying compassionate actions in daily life (Steindl, Kirby & Tellegen, 2020), it is important to assess whether the skills learned in the VR can actually be transferred to real-world situations.

Conclusion

This preliminary study shows that the VR-system designed for Tonglen practice is a potentially effective intervention to foster compassion, in a meditation that could be very difficult or advanced for the general population without VR support. Meditation environments based on VR offer new possibilities to improve the practice of meditation and overcome the obstacles that may be associated with it. However, only a few studies have addressed these issues in empirical studies. A deeper understanding of the effectiveness of practicing compassion meditation using a VR-system is therefore needed. This preliminary study may be considered a first exploration step to gain insight into this field.

Declarations

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Declaration of Conflicts of Interest

The author (s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data availability

The data that support the findings of this study are openly available in Open Science Framework. retrieved from *https://osf.io/fzk95/?view_only=40cbec198dbc40d9a83a82b968c32ea5.*

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Figures

Figure 1

Screenshots of the first phase of meditation.

Note. The participant had its avatar in the mirror located within a virtual environment representing a forest. As the participant inhaled, a light blue smoke (A) and an orange smoke with each exhalation (B) was observed.

(A) (B)

Figure 2

Screenshots of the second phase of the meditation, the Tonglen phase.

Note. Screenshots of the second phase of the meditation, the Tonglen phase. Here the participant observed the avatar of the person with whom they practiced the meditation. The participant inhaled (A) the dark smoke representing avatar's suffering and exhaled (B) clear smoke representing relief from suffering.