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ORIGINAL PAPER

Meditating with One's Avatar in Virtual Reality Enhances Self-Compassion and Perspective-Taking

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Abstract

Objectives Regular self-compassion practice is associated with improved mental health by fostering kindness toward one's suffering and relying on self-related processes like perspective-taking. It is not known whether recently described self-related processes that rely on multisensory bodily signals, induced by exposing participants to an avatar and multisensory stimulation, also contribute to self-compassion meditation. We integrated virtual reality (VR)-based self-compassion meditation with multisensory stimulation promoting self-identification with the avatar.

Method We designed a 17-min-long practice that integrated multisensory stimulation, and audio-guided self-compassion meditation. Twenty-six participants completed an avatar-based self-compassion condition (ASC) and a standard self-compassion condition (SSC) in a within-subject design. Pre- and post-meditation assessments included scores of the State Self-Compassion Scale, Self-Other Four Immeasurables Scale, and an Own Body Transformation task to measure self-compassion, positive and negative qualities, and perspective-taking ability, respectively.

Results Participants in both ASC and SSC conditions demonstrated significantly higher self-compassion scores ($p < 0.001$), increased positive qualities, and reduced negative valence (interaction effect: $p < 0.001$) versus baseline. Perspective-taking ability, as measured in the OBT task, improved in the ASC versus SSC condition.

Conclusions This study showed that (1) incorporating VR-based multisensory stimulation with an avatar into self-compassion practice (ASC) was feasible, (2) both ASC and SSC induced higher compassion ratings characterized by decreased negative and increased positive qualities compared to the baseline, and that (3) ASC meditation improved perspective-taking more than SSC. We proposed that multisensory perceptual cues provided by VR can support perspective-taking, potentially fostering empathetic engagement towards oneself, aiding self-compassion practices.

Preregistration This study is not pre-registered.

Keywords Compassion · Perspective-taking · Virtual reality · Empathy · Own-body transformation

Rooted in traditional contemplative practices such as *Karuṇā* (a Sanskrit term meaning "compassion"), compassion has become an increasingly prominent focus in contemporary psychological research and meditation practice (Cigolla & Brown, 2011; Davidson & Kaszniak, 2015). Compassion is defined as fostering the sensitivity to the suffering of another person, accompanied by the motivation to alleviate that suffering (Goetz et al., 2010; Klimecki & Singer, 2017; Singer

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& Lamm, 2009). It is distinguished from empathy, which is characterized by the ability to be sensitive, to understand, and to experience the affective states of others without necessarily encompassing the motivation to alleviate suffering (i.e., Singer et al., 2009). Thus, compassion highlights feeling for another person instead of feeling along with them (empathy; Singer et al., 2009).

An important element in cultivating compassion during meditation practices is thus the transformation of empathy into a compassionate action (Bibeau et al., 2016; Martin-Allan et al., 2021). For example, seeing a teammate struggling with a challenging task may initially provoke frustration, particularly if it delays the project. However, by empathizing with the teammate's stress and recognizing difficulties, this frustration can shift into compassion, prompting a supportive response. Similarly, traditional compassion training often aims to alter self-centered cognitive, emotional, and behavioral patterns by shifting towards an other-focused perspective, promoting a connection with the other's experience with kindness (Dahl et al., 2015; Davidson & Kaszniak, 2015).

Compassion can also be directed towards oneself (self-compassion) and has been described as "being touched by and open to one's own suffering, not avoiding or disconnecting from it, generating the desire to alleviate one's suffering and to heal oneself with kindness"(Neff, 2003a). Recent meditation research has demonstrated that cultivating self-compassion through regular practice can effectively improve one's own mental health (Campos et al., 2016; Yela et al., 2020; Zessin et al., 2015), including reducing stress, depression, and chronic pain, and increasing resilience and emotional regulation (Gilbert & Procter, 2006; Green & Kinchen, 2021; Lanzaro et al., 2021). Compared to compassion directed towards others, self-compassion is a different but related process that strongly relies on self-related processing, including perspective-taking and empathy abilities. To quantify changes in self-compassion, previous researchers have used the Self-Compassion Score (Neff, 2003b), which measures different elements of self-compassion including self-kindness, common humanity, and mindfulness (Zessin et al., 2015), and the Self-Other Four Immeasurables (SOFI) Scale (Kraus & Sears, 2009) that captures both self-directed and other-directed aspects of each immeasurable quality, reflecting loving kindness, compassion, joy and acceptance in Buddhist teachings.

Concerning self-related processes, perspective-taking is a key process and has been associated with a higher-level form of the sense of self (i.e. narrative self) and a minimal (bodily) self (Damasio, 1999; Gallagher, 2000; Legrand & Ruby, 2009; Millière et al., 2018; Northoff et al., 2006; Seth & Tsakiris, 2018). The narrative self refers to a higher-level cognitive self, involving self-related thoughts, language, and explicit perspective-taking ability, that shape our life narrative and core self-related beliefs. The minimal self, instead, is not extended in time and centers on conscious bodily experiences such as body ownership, self-identification with the body, and the first-person perspective based on multisensory bodily perception (Ionta et al., 2011; Serino et al., 2015; Tsakiris, 2017; Yang et al., 2025). The minimal self can be altered experimentally leading to changes in body ownership and self-identification through the manipulation of specific multisensory bodily signals. In such multisensory paradigms using virtual reality (VR) in the full-body illusion (FBI) (Bayer et al., 2023; Ehrsson, 2007; Lenggenhager et al., 2007; Noel et al., 2015; Preston et al., 2015; Salomon et al., 2016; Schmalzl et al., 2011), participants receive touches on their body while viewing an avatar from a third person perspective (3PP; seen from behind and projected in front of them and receiving the same tactile stimulation), inducing illusory self-identification with the avatar.

Such experimental manipulations of the minimal self, using VR, have also been linked to cognitive perspective-taking ability and empathy (Heydrich et al., 2021; Mohr et al., 2010). Perspective-taking is commonly assessed using the Own-Body Transformation (OBT) task, in which participants are shown the image of a human figure with a hand that is highlighted and are asked to imagine themselves to take the perspective and position of the figure and to judge whether the marked hand of the figure would be their right or left hand (Arzy et al., 2006; Blanke et al., 2005; Schwabe et al., 2009; Zacks et al., 1999). Notably, exposure to the FBI has been shown to modulate reaction times during the OBT task, suggesting that alterations in bodily self-representation can influence perspective-taking performance. The relationship between perspective-taking and empathy has also been demonstrated behaviorally. For example, Heydrich et al. (2021) found that individuals with higher empathy scores were faster in perspective-taking (Heydrich et al., 2021; Mohr et al., 2010). At the neural level, these processes appear to rely on partially overlapped brain activations. The temporoparietal junction (Blefari et al., 2017; Ionta et al., 2011) as well as interoceptive cortices (Ehrsson et al., 2007; Park et al., 2018) have been identified as key regions of the minimal self. These regions have also been implicated in perspective-taking (Chen et al., 2016; Tadi et al., 2009; Zacks et al., 1999), as well as empathy (Singer & Klimecki, 2014; Singer & Tusche, 2014; Tholen et al., 2020; Tusche et al., 2016). As these diverse functions share cortical structures, they might potentially overlap in brain activity during VR-based meditation.

Although the rationale for the present study is not that bodily perspective-taking and compassion are identical processes, prior behavioural and theoretical work suggests that the way one represents one's own body (minimal self) may shape how one shifts perspective toward oneself. On this basis, we tested whether an avatar-based embodiment manipulation would affect both an embodied perspective-taking task and a state compassion-related outcome, without assuming that both measures should necessarily change in parallel. Some forms of meditation rely significantly on mental imagery and VR has been shown to support imagery by enabling participants to construct, sustain, inspect, and transform the imagery during meditation (Bedford, 2012; Kozhevnikov et al., 2009; Navarrete et al., 2021). These VR-based meditations may offer potential advantages as a research and intervention platform, including controlled inclusions of embodied self-representations (Cebolla et al., 2019), and the ability to combine guided practice with multisensory cues. These features may be especially relevant for studying self-related contemplative practices (such as self-compassion) in which embodiment and self-related perspective are central. Yet, it remains speculative whether such VR-supported meditative practices modulate the shared psychological mechanisms underlying compassion, empathy, and the minimal self.

Given the impact of VR and the evidence linking processes of compassion-empathy and minimal self, we speculated that both processes may also be important for self-compassion meditation. The aim of the present study was to investigate whether a VR-based self-compassion intervention incorporating multisensory stimulation could enhance self-compassion and perspective-taking abilities. To address this aim, we designed a VR-based self-compassion practice that integrates meditation guidance with multisensory stimulation characterized by cardio-visual stimulation between the participant and their seen avatar in VR, as the participant and avatar meditated together. Extending a recently described VR meditation platform that allows immersing participants in a three-dimensional environment during meditation practice (Vuarnesson et al., 2024; Yang et al., 2025), participants were guided through two separate self-compassion meditation conditions. In one condition, participants meditated together with their avatar sitting in front of them. The avatar was also illuminated regularly with cardio-visual stimulation (avatar self-compassion meditation, ASC). In the other condition, participants practiced a standard self-compassion meditation (SSC) with the same audio guidance, but without the avatar. Before and after both meditation conditions, we measured self-compassion using the State Self-Compassion Scale and SOFI scale, perspective-taking ability using the OBT task, and cardiac activity (ECG). We hypothesized that self-compassion, as assessed by questionnaires, and perspective-taking ability, as measured by the OBT task, would improve following self-compassion meditations compared to baseline levels, expecting that the ASC condition would facilitate some of these effects.

Method

Participants

A total of 30 healthy participants were recruited for the current study, with 26 completing all tests successfully. The sample size was determined based on an effect size (0.663) reported by Blanke et al. (2005), for the difference in reaction time between front-facing and back-facing figures in the own-body transformation task. A paired t-test with an alpha level of 0.05 and a power of 0.9 was used to estimate the required sample size, calculated using G*Power 3.1.9.7 software (Faul et al., 2007). Participants in the study were predominantly right-handed, with two left-handed individuals, and all were fluent in English. The group comprised 13 males and 13 females, with ages ranging from 20 to 49 years, and a mean age of 27.15 years (standard deviation: 8.15 years). Participants were all non-meditators as none had prior experience with regular meditation. Participants were recruited via a custom-designed online platform and social media advertisements. Exclusion criteria included the presence of any neurological or psychiatric disorder, as well as a history of substance abuse. Information on race, ethnicity and socioeconomic status was not systematically collected. Future studies could investigate how these factors influence self-compassion practice and explore the ability of VR to induce embodiment for an avatar of a different gender or skin color (Banakou et al., 2016; Peck et al., 2013). Participants provided informed consent prior to the experiment, and received compensation of 20 CHF per hour for their participation upon completion. This research was approved by the Swiss Ethics Committees on research involving humans (Project ID: 2021–00358).

Procedure

The experiment followed a single-factor within-subject design to compare subjective reports, behavioral, and electrocardiogram (ECG) measurements between two conditions, each involving a meditation session of around 17 min in immersive VR. The order of the two conditions (ASC, SSC) was randomized across participants.

The experiment was conducted in a dedicated room designed to create a relaxing atmosphere, with dimmed lights, a soft square carpet for participants to walk on barefoot, and comfortable cushions at the center where they sat during the meditations. Once participants were comfortably settled, they were equipped with a VR headset and earphones. They were then immersed in the virtual laboratory environment (Fig. 1B) for a few minutes, allowing them

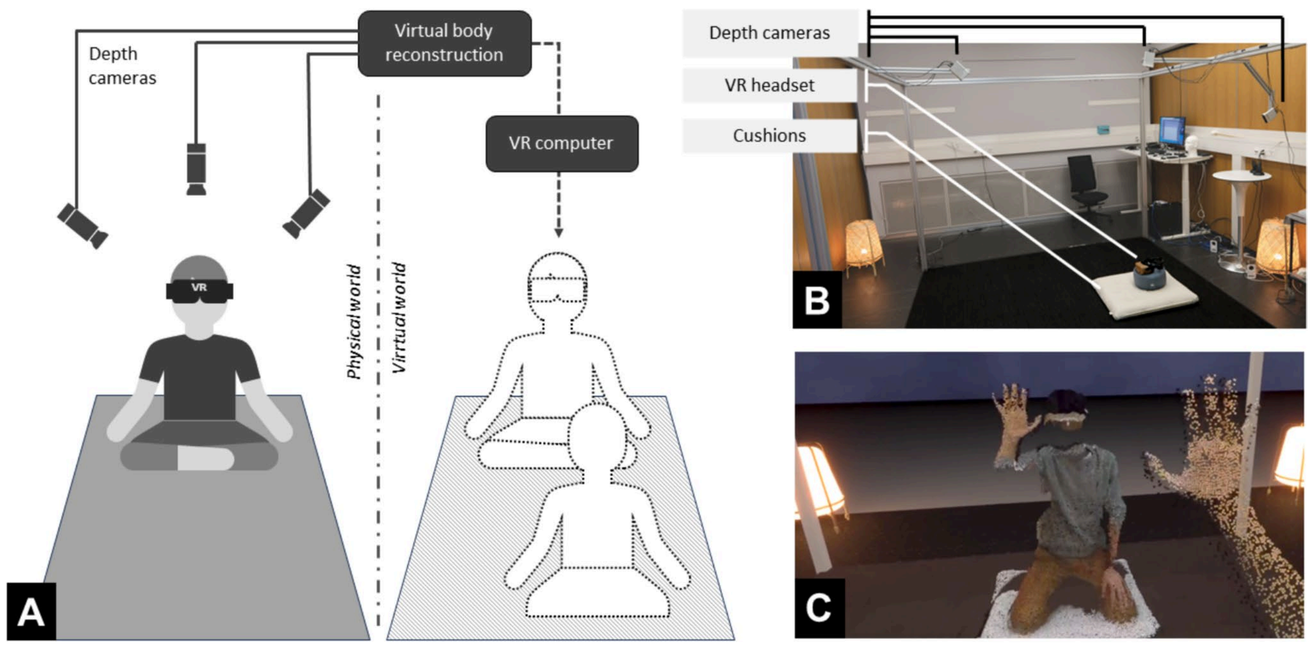

Fig. 1 Experimental Setup. **A**. Conceptual framework used for the avatar self-compassion (ASC) condition. Participants wearing a VR headset and saw the VR world, were filmed with 3 depth cameras; these images are used to reconstruct a virtual body. This virtual body (avatar) was integrated into the VR world at a distance and as sitting in front of the sitting particpant. **B**. The VR setup includes depth cameras, a VR headset, computers, and a comfortable cushion for meditation. **C**. First-person view of a participant looking at the avatar, which is seen as sitting and facing the participant. Participants were also seeing their body in VR at the physical position (i.e., when looking down or at their hand; for example their right hand when lifting it into their visual field)

to become familiar with the interaction methods and the view of their avatar. Participants then completed several baseline measurements before the meditation (including ASC and SSC), serving as a reference for post-meditation assessments.

Following the baseline measurements, participants were guided in their meditation by pre-recorded instructions (see Online Resource 1 for the full instructions) inviting them to meditate in VR. After a welcome phase, the scene transitioned to a night sky environment. After looking around and discovering this new environment, participants were instructed to close their eyes. During 5 min, participants were invited to experience the present moment and to focus on body awareness and breathing. The two conditions then began to diverge: In the ASC condition participants were asked to open the eyes and were informed that an image of themselves would be in front of them. In the SSC condition nothing was mentioned and participants were instructed to keep their eyes closed. Apart from that, both conditions continued with the exact same instructions; participants were guided to express love and kindness towards themselves, invited to silently repeat statements such as "May I be well and happy", focusing on the cultivation of self-compassion. Participants kept the VR headset on for the whole exercise in both conditions. In the ASC condition, participants encountered a front-facing visual representation of themselves, i.e., an avatar showing their tracked body in VR in a non-mirrored orientation (Fig. 1C). To establish a connection with the avatar, participants were instructed to perform simple movements, such as bending their heads while observing their avatar performing the same actions. Furthermore, the avatar was animated to flash synchronously with the participant's own ongoing heartbeat (synchronous cardio-visual stimulation). In the earlier studies, such synchronous stimulation has been found to enhance the bodily experience and promote self-identification with the avatar and a drift in self-location towards the avatar, as compared with an asynchronous cardio-visual control stimulation (Aspell et al., 2013; Blefari et al., 2017; Heydrich et al., 2018). In the present study, we integrated cardio-visual stimulation between participant and avatar into the meditation procedure in order to investigate whether the manipulation of bodily self-consciousness (i.e., an increase in self-identification with the avatar) had an impact on self-compassion ratings. The SSC condition followed the same meditation guidance to cultivate self-compassion but differed from the ASC condition as it had no involvement in self-avatar visualization and visual-cardio synchronization. Participants were instead instructed to close their eyes and mentalize themselves seated in the present moment, focusing on expressing love and kindness toward their bodies.

Virtual Reality Experimental Setup The VR immersion platform, including a VR headset for visual immersion (HP Reverb G2, Hewlett-Packard, USA, 107° diagonal FOV, 2160 × 2160 per-eye) and noise-canceling earphones for audio immersion (DH Gold series, Italy), was developed with Unity3D (Unity Technologies, USA) and features two audio-visual virtual environments. The first is the virtual laboratory, a 3D replica of the actual experimentation room, for welcoming participants and administering questionnaires. The second is an open environment with a night sky for immersing participants in a relaxing setting during meditation. In addition, a custom built body scanning system captures and reconstructs the 3D representation of people's body (four Kinect Azure cameras, Microsoft, USA, (Albert et al., 2019). It is used to provide participants with a real-time virtual body representation (their avatar), as well as to record and later replay the experimenter giving instructions and verbal guidance, thus providing the participant with the illusion of being co-located with the virtual guide.

ECG Recordings The ECG was recorded during the meditation conditions. All ECG analyses were done in MATLAB (The MathWorks, Inc.). The ECG signal was initially filtered using high-pass and low-pass frequencies of 0.1–40 Hz. The R-peaks of heartbeats were based on the decomposition of discrete wavelet transform (Biran & Jeremic, 2023) and it followed the same procedure as the earlier study (Yang et al., 2025). These peak detection results were visually inspected for all participants throughout the experiment. Heart rate variability was assessed using the root mean square of successive R-R intervals (RMSSD).

Measures

Several measurements were conducted before and after the meditation, serving as a reference for post-meditation assessments. These include the behavioral OBT task to assess the perspective-taking ability (see details in the section below), along with several questionnaires including the 18-item State Self-Compassion Scale (SSCS) to evaluate the aspects of self-compassion on a 5-point Likert Scale ranging from 1 (*almost never*) to 5 (*almost always*) (Neff, 2016), and the 16-item Self-Other Four Immeasurables (SOFI) to measure the experience of positive (i.e., friendly, joyful, accepting, compassionate) versus negative (i.e., mean, angry, hateful, cruel) qualities related to oneself and others on a 5-point Likert scale ranging from 1 (*very slightly or not at all*) to 5 (*extremely*) (Kraus & Sears, 2009; Logie & Frewen, 2015). In the present study, McDonald's omega for the State Self-Compassion Scale was 0.64 at baseline, 0.88 after the ASC condition, and 0.89 after the SSC condition. For the Self-Other Four Immeasurables Scale, McDonald's omega was 0.78 at baseline, 0.77 after the ASC condition, and 0.90 after the SSC condition. Overall, these values indicate modest to good internal consistency across measurement points, although the estimates should be interpreted with caution given the modest sample size.

The OBT task, designed to quantify perspective-taking ability and based on the earlier study by Blanke et al. (2005), was administered before and after each meditation condition (Fig. 2A for the procedure). Participants were shown an image of a human figure that either faced toward or away from them, with one hand marked by a gray glove (either the left or right hand, Fig. 2B). In each trial, the figure image was displayed for 200 ms, followed by a fixation cross presented for a randomized duration between 500 and 1200 ms. Participants were instructed to adopt the figure's perspective and identify whether the marked hand was left or right by pressing a button with the index finger and middle finger of their dominant hand. The task included a total of 192 trials, divided into four trial types based on the figure's orientation (front-facing or back-facing) and the marked hand (left or right). Outliers were removed to analyze the behavioral data if the reaction time exceeded 1.5 times the Interquartile range (IQR, see Cho & Eo, 2016; Dash et al., 2023). A total of 6.69% of trials were identified as outliers and excluded from further reaction time analysis.

Data Analyses

For measures including the State Self-Compassion Scale, SOFI, and physiological measures, Linear Mixed Effect (LME) models were applied to examine the effect of experimental conditions (ASC, SSC, and baseline). To assess accuracy and reaction time in the OBT task, we calculated contrast differences from the baseline separately for the ASC and SSC conditions. An LME model was then applied to examine the effects of these conditions on the observed differences. For all the models mentioned above, the participant number and the order of meditation sessions were set as random effects. No additional multiple-comparison correction was applied to the LME analyses of questionnaire outcomes, because these models were planned on a limited set of outcome measures. In contrast, Bonferroni correction was applied to the correlation analyses between reaction times (RTs) and State Self-Compassion Scale subscale scores, as these involved multiple tests and were considered more exploratory.

Results

Score of the State Self-Compassion Scale

We found a main effect of measurement (baseline, ASC meditation, and SSC meditation) on the total score of

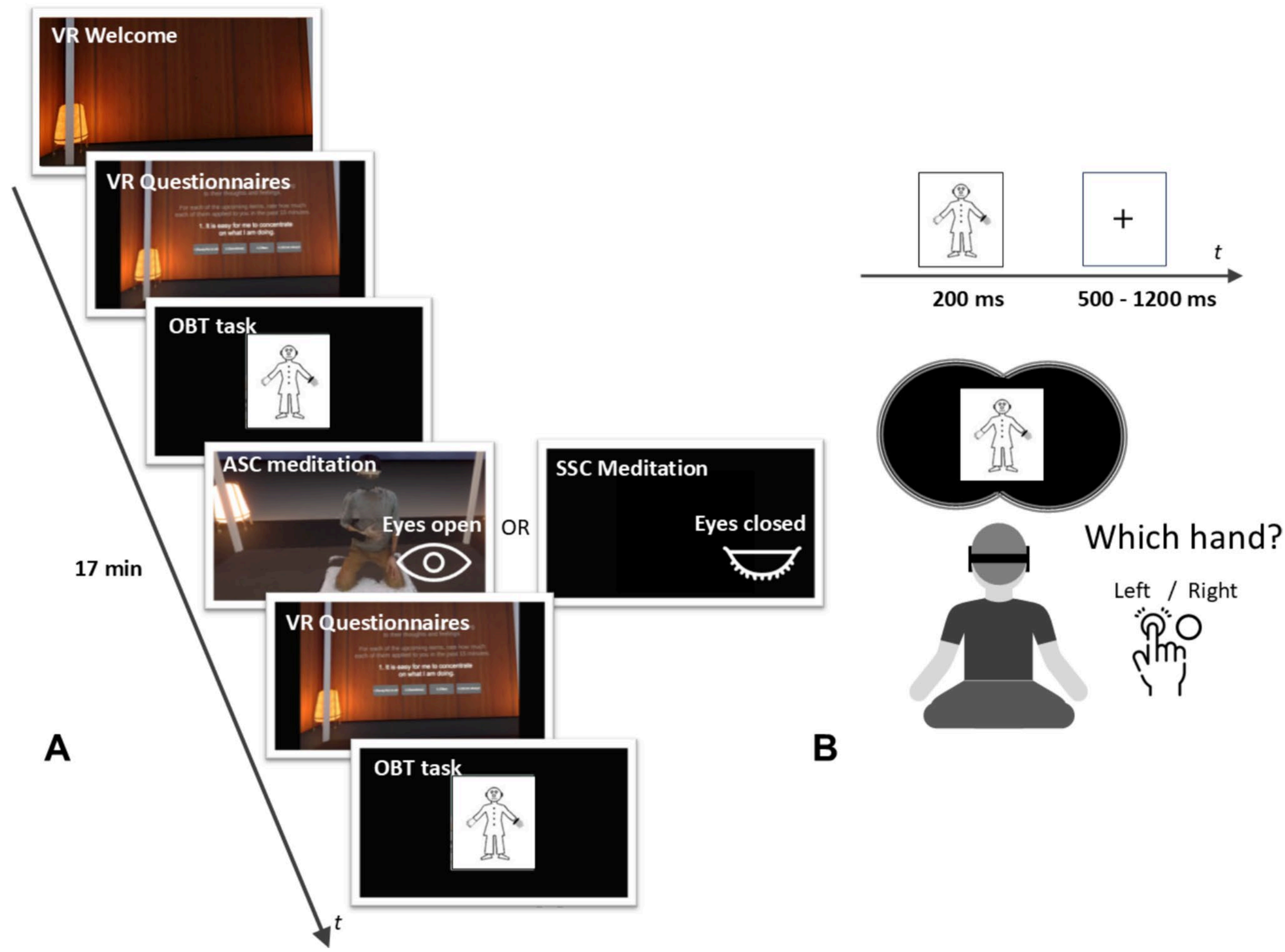

Fig. 2 **A**) A simplified flow of one typical block in the study. The experiment includes two blocks, one for the avatar self-compassion condition (ASC) and one for the standard self-compassion condition (SSC). Each block consists of meditation sessions followed by subjective evaluations using questionnaires in VR (State of Self-Compassion Scale, Self-Other Four Immeasurables Scale) and a behavioral task in VR (Own-body transformation task, OBT). The order of the two meditation conditions was counterbalanced across participants. **B**) Illustration of a single trial of the OBT task. Participants were instructed to adopt the figure's perspective and indicate whether the marked hand was left or right

self-compassion ($\chi^2(2)$ = 29.46, $p < 0.001$, See Fig. 3). The post-hoc comparisons further showed that, compared to the baseline, participants had a higher total score of self-compassion after both conditions, in the ASC (*estimate* = 0.38, *SE* = 0.058, $t(1376) = 6.68$, $p < 0.001$, *Cohen's d* = 0.94; see Table 1 for descriptive results) and the SSC meditation (*estimate* = 0.32, SE = 0.058, $t(1376) = 5.53$, $p < 0.001$, *Cohen's d* = 0.80). The two meditation conditions did not differ significantly in the total score (*estimate* = 0.066, *SE* = 0.058, $t(1376) = 1.15$, $p = 0.25$, *Cohen's d* = 0.18). Moreover, for the dimensions of the State Self-Compassion Scale, we found significant main effects in the sub-scales of over-identification, common humanity, self-judgment, mindfulness, and isolation but not for self-kindness (see Table 1). These dimensions did not differ between the two meditations in the post-hoc comparisons (see Table 1 for detailed statistics). These data show that self-compassion as measured by the State Self-Compassion Scale was elevated in the ASC and SSC conditions.

SOFI Score

Using the LME model, we tested the SOFI scores in the three-way interaction of valence (2 levels, positive vs. negative) * condition (3 levels, ASC, SSC, and baseline) * object (2 levels, self vs. others). There was a main effect of valence ($\chi^2(1)$ = 1173, $p < 0.001$) with positive valence ($M = 3.97$, $SD = 0.53$) higher than negative valence ($M = 1.57$, $SD = 0.50$, see Table 2). A significant interaction between

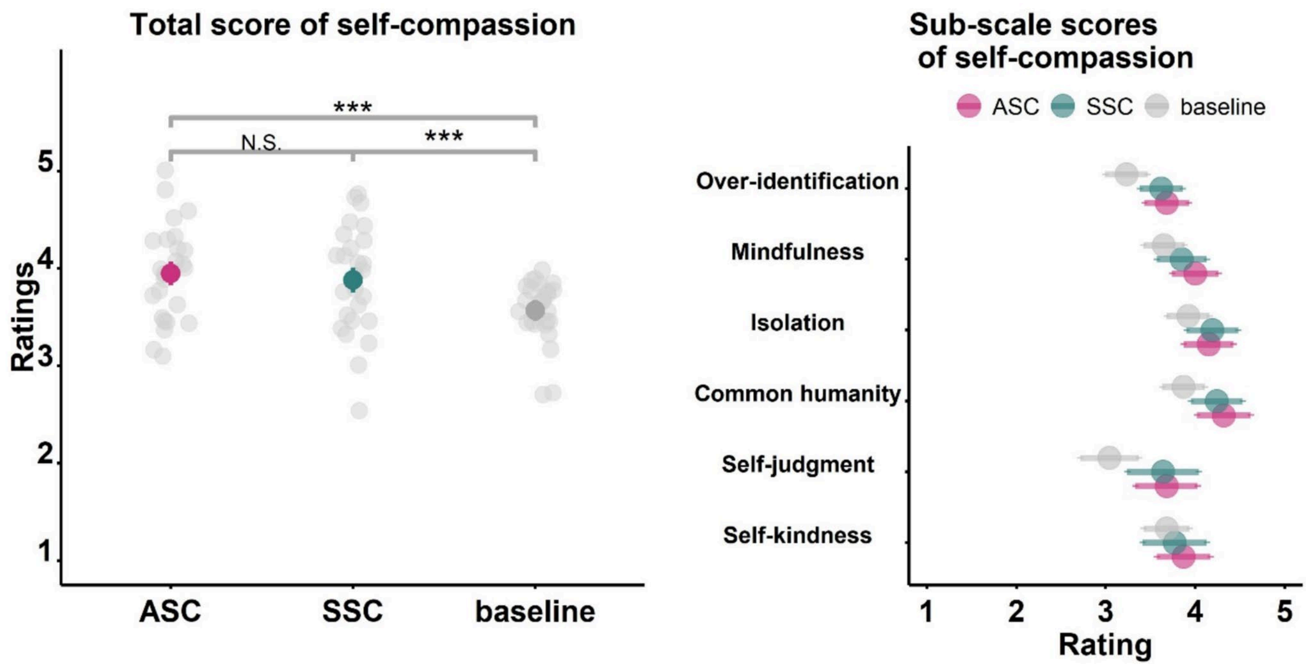

Fig. 3 Scores on the State Self-Compassion Scale were assessed at baseline and after both, the avatar self-compassion (ASC) condition and standard self-compassion (SSC) meditation sessions. The self-compassion scores in the baseline, and after the ASC and SSC meditation (error bar represents 95% confidence interval, same as below). The main effect of measurements (baseline, ASC, and SSC) was found. Both meditation conditions showed significant increases in the total score of self-compassion compared to the baseline. No difference has been found between the two meditation conditions in the total score or in any specific dimensions of self-compassion

Table 1 The subjective reported scores on the State of Self-Compassion Scale. The main effect of measurement was found for the total score and dimensions including self-judgment, common humanity, isolation, mindfulness, and over-identification

Component	ASC condition	SSC condition	Baseline	LME main effect			Post-hoc comparisons between ASC and SSC					
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*df*	χ^2	*p*	*Estimate*	*SE*	*df*	*t*	*p*	*Cohen's d*
Total score	3.95 (0.75)	3.88 (0.80)	3.57 (0.71)	**2**	**29.47**	$\mathbf{3.99*10^{-7}}$	0.67	0.06	1376	1.15	0.25	0.18
Self-kindness	3.87 (0.75)	3.77 (0.89)	3.68 (0.64)	2	3.56	0.17	0.10	0.10	154	1.00	0.32	0.18
Self-judgment	3.68 (0.64)	3.64 (0.99)	3.04 (0.82)	**2**	**45.47**	$\mathbf{1.34*10^{-10}}$	0.04	0.11	154	0.36	0.72	0.08
Common humanity	4.32 (0.75)	4.24 (0.72)	3.87 (0.60)	**2**	**22.00**	$\mathbf{1.67*10^{-10}}$	0.08	0.10	154	0.75	0.46	0.15
Isolation	4.15 (0.68)	4.19 (0.71)	3.92 (0.58)	**2**	**7.66**	**0.02**	−0.04	0.11	154	−0.36	0.72	−0.06
Mindfulness	4.00 (0.65)	3.85 (0.70)	3.65 (0.57)	**2**	**11.43**	**0.003**	0.15	0.10	154	1.49	0.14	0.27
Over-identification	3.68 (0.61)	3.62 (0.59)	3.23 (0.59)	**2**	**6.34**	$\mathbf{6.34*10^{-5}}$	0.06	0.11	154	0.58	0.56	0.12

valence and object ($\chi^2(1) = 10.09$, $p = 0.002$) revealed that for positive qualities, ratings were slightly higher for others ($M = 4.12$, $SD = 0.42$) than for oneself ($M = 3.83$, $SD = 0.77$), while for negative ratings, ratings were higher for oneself ($M = 1.65$, $SD = 0.60$) than for others ($M = 1.49$, $SD = 0.49$).

Table 2 The main effects and interactions of valence (positive vs negative), object (self vs others), and condition (avatar self-compassion [ASC]; standard self-compassion [SSC]; and baseline) in the Linear Mixed Effect (LME) model for Self-Other Four Immeasurables (SOFI) scores

LME Factors	LME main effect		
	df	χ^2	*p*
Valence	**1**	**1173.00**	< 0.001
Object	1	0.88	0.35
Condition	2	1.70	0.43
Valence * Object	**1**	**10.09**	**0.002**
Valence * Condition	**2**	**60.31**	< 0.001
Object * Condition	2	0.15	0.93
Valence * Object * Condition	2	0.67	0.72

In addition, a significant interaction between valence and condition ($\chi^2(2) = 60.31$, $p < 0.001$) was demonstrated: For positive valence, ratings were the highest in the ASC condition ($M = 4.07$, $SD = 0.53$), followed by the SSC condition ($M = 4.01$, $SD = 0.64$) and baseline ($M = 3.85$, $SD = 0.57$). For negative valence, ratings were lowest in the ASC condition ($M = 1.44$, $SD = 0.41$), followed by the SSC condition ($M = 1.53$, $SD = 0.56$) and baseline ($M = 1.75$, $SD = 0.61$; See Table 2). Post-hoc comparisons indicated significant or marginal improvements in the SOFI subscale scores for both ASC and SSC conditions compared to baseline. No significant differences between the ASC and SSC conditions across any subscale were observed (see Table 3). These results suggest that both ASC and SSC interventions led to comparable improvements in positive and negative qualities relative to baseline measurements, indicating the effectiveness of both approaches in enhancing SOFI scores.

Perspective Taking (OBT Task)

First, we replicated that participants' responses were slower for front-facing avatars in the OBT task compared to the back-facing figures ($\chi^2(1) = 114.09$, $p < 0.001$;

Table 3 Descriptive results and post-hoc comparisons of Self-Other Four Immeasurables (SOFI) component scores (negative, positive, self, and others) between measurement during the avatar (ASC), standard (SSC) self-compassion meditation conditions, and the baseline (BL)

Factors		ASC condition	SSC condition	Baseline	Comparison	Post-hoc comparisons					
Object	Valence	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)		*Estimate*	*SE*	*df*	*t*	*p*	*Cohen's d*
Others	Negative	1.37 (0.43)	1.46 (0.59)	1.65 (0.57)	ASC vs. SSC	−0.10	0.07	824	−1.34	0.21	−0.28
					ASC vs. BL	**−0.29**	**0.07**	**824**	**−4.05**	**< 0.001**	**−0.79**
					SSC vs. BL	**−0.19**	**0.07**	**824**	**−2.70**	**0.01**	**−0.45**
Others	Positive	4.22 (0.46)	4.13 (0.54)	4.00 (0.44)	ASC vs. SSC	0.09	0.07	824	1.21	0.25	0.21
					ASC vs. BL	**0.22**	**0.07**	**824**	**3.10**	**0.003**	**0.55**
					SSC vs. BL	0.13	0.07	824	1.89	0.07	0.31
Self	Negative	1.51 (0.48)	1.60 (0.64)	1.85 (0.77)	ASC vs. SSC	−0.09	0.07	824	−1.21	0.25	−0.33
					ASC vs. BL	**−0.34**	**0.07**	**824**	**−4.72**	**< 0.0001**	**−0.77**
					SSC vs. BL	**−0.19**	**0.07**	**824**	**−2.70**	**0.01**	**−0.56**
Self	Positive	3.91 (0.76)	3.88 (0.88)	3.69 (0.83)	ASC vs. SSC	0.03	0.07	824	0.41	0.69	0.06
					ASC vs. BL	**0.22**	**0.07**	**824**	**3.10**	**0.003**	**0.42**
					SSC vs. BL	**0.19**	**0.07**	**824**	**2.70**	**0.01**	**0.33**

Table 4 Descriptive results baseline and post-test measurements for front-facing and back-facing figures in the Own-Body Transformation (OBT) task

Measurement	ASC condition		SSC condition	
	Baseline	Post-test	Baseline	Post-test
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Accuracy				
Back-facing	0.93 (0.13)	0.97 (0.06)	0.94 (0.09)	0.97 (0.05)
Front-facing	0.93 (0.08)	0.96 (0.07)	0.92 (0.13)	0.98 (0.03)
Reaction Time				
Back-facing	553.99 (134.68)	492.47 (103.57)	529.10 (127.82)	503.05 (128.57)
Front-facing	664.19 (131.68)	589.23 (101.69)	610.14 (124.26)	589.42 (125.32)

Front-facing: $M = 613.25$, $SD = 97.29$; Back-facing: $M = 519.66$, $SD = 105.41$). Second, there was a learning effect across all trials: reaction times decreased significantly between baseline and post-test ($\chi^2(1) = 27.34$, $p < 0.001$, see Table 4 for descriptive results).

Next, to evaluate the effects of self-compassion meditation, changes in reaction time (RT) and accuracy were analyzed by subtracting baseline from post-test measurements. The ASC condition exhibited a significantly larger decrease in RT ($M = -68.24$, $SD = 80.44$) compared to the SSC condition ($M = -23.39$, $SD = 107.37$; $\chi^2(1) = 10.53$, $p = 0.001$). Moreover, this decrease in RT was significantly below zero for the ASC condition ($t(25) = -4.33$, $p = 0.002$, *Cohen's d* $= -0.85$), whereas no significant change from zero was observed for the SSC condition ($t(25) = -1.11$, $p = 0.28$, *Cohen's d* $= -0.22$). These findings suggest that the ASC meditation condition leads to more substantial reductions in reaction time (Fig. 4A).

Lastly, to explore the relationship between performance on the OBT task and subjective self-compassion, we analyzed the correlation between the reaction time (RT) difference (ASC minus SSC, as described below) and the subscales of the Self-Compassion Scale. The analysis revealed a significant positive correlation between the RT difference and the over-identification subscale ($r(25) = 0.40$, $p = 0.04$, see Fig. 4B), but not between the RT difference and any of the other subscales (see Online Resource 2).

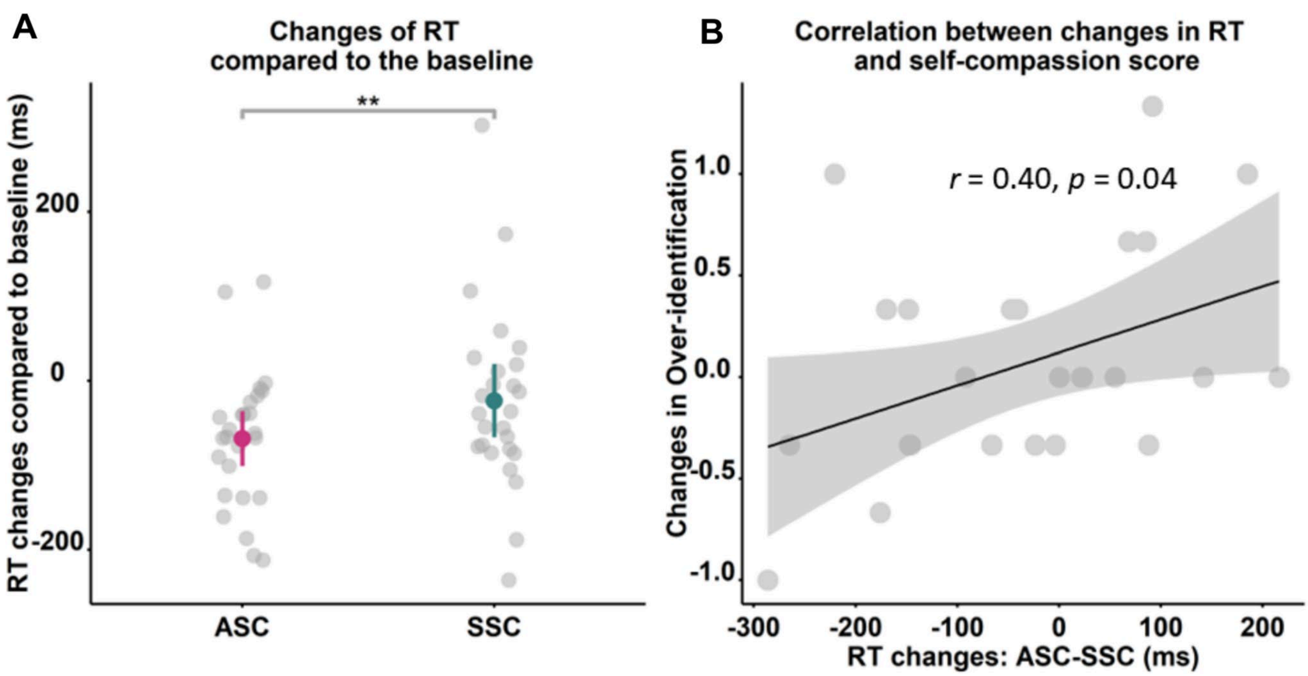

Fig. 4 **A**) Behavioral changes in the Own-Body Transformation (OBT) task were observed following meditation compared to the baseline (zero represents a score equal to the baseline, and a negative value represents a reduction compared to the baseline). Our data showed a greater reduction of the reaction time (RT) in the OBT task in the ASC condition compared to the SSC condition. The face (front vs. back) of the body and the order of the meditations were counterbalanced in this analysis. **B**) A positive correlation was observed between the RT difference in the front-facing position and the over-identification subscale of the self-compassion score. The x-axis and y-axis represent values calculated by subtracting the SSC condition from the ASC condition

Table 5 Descriptive and statistical results of the ECG analysis. The inter-beat interval, heart rate and heart rate variability were found to be equivalent between the ASC and SSC conditions, as indicated by the Bayes factors

Index	ASC condition	SSC condition		LME		*BF10*
	M (SD)	*M (SD)*	*df*	χ^2	*p*	
Inter-beat interval (ms)	855.67(124.23)	856.54 (107.87)	1	0.006	0.94	0.28
Heart beat per minute	71.55 (10.44)	71.15 (9.18)	1	0.17	0.68	0.28
Heart rate variability	60.06 (29.37)	59.90(37.32)	1	0.002	0.97	0.28

Control Analysis of the ECG Signals

The heart rate and heart rate variability were measured during the two meditation sessions. No difference were found across both conditions in inter-beat interval and heart rate. There was no difference in heart rate variability between both conditions (Table 5).

Discussion

Self-related processes such as perspective-taking have been argued to be essential for meditation practices aimed at increasing self-compassion (Dahl et al., 2015). The present study is based on previous evidence that perspective-taking shares behavioral brain mechanisms with own-body perception (Blefari et al., 2017; Heydrich et al., 2021; Ionta et al., 2011; Singer & Klimecki, 2014; Singer & Tusche, 2014; Tholen et al., 2020; Tusche et al., 2016). We thus modulated the perception of one's own body during self-compassion practice by presenting a self-avatar in cardio-visual synchronization that was shown as sitting and meditating with the participant, while participants followed a standard audio-guided self-compassion meditation. We report that the ASC and the standard self-compassion meditation (SSC) both led to higher subjective self-compassion scores, increased positive qualities on the SOFI scale, and reduced negatively-valenced qualities. Whereas there were no differences between ASC versus SSC for these scores, we found that the ASC showed increased perspective-taking ability compared to the SSC condition. Control analyses confirmed that these effects were not driven by physiological factors, such as heart rate or heart rate variability.

Using a VR platform that immersed participants in a virtual environment, we developed a self-compassion meditation that complemented audio-based guidance of self-compassion with real-time cardio-visual synchronization between the participant and their self-avatar while meditating together. This procedure integrated the full-body illusion known to induce self-identification with the avatar (Bayer et al., 2023; Ehrsson et al., 2007; Heydrich et al., 2018; Lenggenhager et al., 2007) into self-compassion practice. Thus, compared to SSC, the cardio-visual synchronization with the avatar in the ASC provided additional multisensory stimulation to recruit self-related perceptual processes in addition to those of self-compassion facilitated by audio-based guidance. Our findings revealed that this ASC meditation benefited participants in their self-compassion and overall affective states, compared to the baseline, and that these changes were equivalent to changes in the SSC condition. The obtained scores of the Self-Compassion Scale (SCS) were comparable to those reported in existing studies of self-compassion (Neff, 2016) including meditators (Neff et al., 2017), as well as when using VR (Cebolla et al., 2019). Studies have reported increased heart rate variability following compassion-based interventions (Di Bello et al., 2021; Steffen et al., 2021). However, in our study, HRV was comparable between the ASC and SSC conditions, suggesting that both conditions did not modulate HRV differently during meditation.

Importantly, although the ASC condition showed greater improvement in OBT performance than the SSC condition, both conditions showed a similar increase in state self-compassion. This pattern suggests that avatar-based embodiment may preferentially influence an embodied self-related process (bodily perspective-taking) without necessarily enhancing the immediate self-reported compassion outcome more than when practicing without the avatar. Although self-related embodied perspective-taking and compassion-related self-processes may involve partially overlapping mechanisms, overlap at the neural level should not be interpreted as functional equivalence. In the present study, the value of the VR setup therefore appears to lie more in its capacity to modulate a self-related embodied process rather than in producing stronger short-term self-compassion benefits than standard audio-guided practice. Accordingly, the present findings do not establish enhanced self-compassion efficacy for ASC, nor do they demonstrate any additional emotional benefit from the embodied process. The practical advantage of the VR setup for this meditation protocol remains to be determined in follow-up studies using longer sessions with more repetitions.

Several factors may explain why the current ASC condition did not show an advantage over SSC condition. First, the avatar in the ASC condition was located outside the peripersonal space (80–100 cm), within which multisensory bodily effects dominate (Blanke et al., 2015; Noel et al., 2015; Serino et al., 2015). Second, the pixelated animation of the avatar may have degraded the quality of participants' co-perception of their body and avatar, hence limiting the potential facilitation effects of self-compassion. Future studies should investigate these points and their potential impact on self-compassion, by adapting the VR design.

Analysis of reaction times in the OBT task showed that the ASC condition improved perspective-taking abilities. Perspective-taking is an essential aspect of mindfulness meditation (Klimecki et al., 2014), cultivating disengagement from egocentrism and isolation (Batson et al., 1997; Decety & Jackson, 2004). Perspective-taking has also been conceptualized as a central process of compassion training (Dahl et al., 2015; Neff, 2003a). Instead of questionnaire-based subjective measurement to access perspective-taking among participants (i.e., Edwards et al., 2017; Suzuki & Sakamoto, 2023), we quantified perspective-taking by the OBT task (Parsons, 1987; Tomasino et al., 2016). The OBT is a mental transformation task of participants' body and perspective and has been linked to activations in the temporal-parietal junction (Arzy et al., 2006; Blanke et al., 2005; Schwabe et al., 2009), a region also activated during compassion meditation (Kang & Falk, 2020; Lutz et al., 2008) and more strongly activated in meditation experts than in meditation novices (Gundel et al., 2018). Future neuroimaging studies should investigate this interesting overlap of functional brain mechanisms, also testing short-term and longer-term changes and how these may differ between ASC and SSC. Additionally, it is well-established that other multisensory manipulations, including the visual-tactile, and visual-respiratory synchrony, have been shown to significantly alter the sense of self (Betka et al., 2020; Lenggenhager et al., 2007) and activate the temporal-parietal junction (Ionta et al., 2011, 2014; Zeugin et al., 2020). Such stimulations have also been shown to modulate the performance on the OBT task (Ionta et al., 2012, 2013). Also, the cardio-visual stimulation, by linking participants' cardiac rhythms with the luminance of avatars in VR, may have enhanced bodily self-awareness and self-identification through interoceptive–exteroceptive integration (Aspell et al., 2013; Suzuki et al., 2013), thereby reinforcing embodied aspects of the minimal self. Collectively, the present data suggest that self-compassion meditation shares mechanisms with multisensory own-body perception as well as mental imagery related to one's own body.

Self-compassion practices are often described as relying on emotional aspects of perspective-taking and empathy. However, an increasing number of studies have highlighted the cognitive components of these processes as indispensable for cultivating self-compassion and emotional, cognitive and bodily-perceptual mechanisms of perspective taking overlap (Dahl et al., 2015; Marshall et al., 2020; Quesque et al., 2024). While both perspective taking and self-compassion have been suggested to belong to constructive practices by Dahl and colleagues (2015), perspective-taking as currently measured in the OBT is a form of perception orientation, while the practice of self-compassion primarily focuses on relation orientation and values orientation, which can then, in a next step, impact perceptive processes. Future work should explore whether in addition to affecting perceptual perspective taking, the present VR-supported ASC also modulates emotional components of perspective taking.

A recently emerging topic of growing interest in meditation research is embodiment, which examines cognitive and emotional patterns linked to bodily perceptual awareness. For example, experienced meditators have shown an altered sense of body boundaries and sense of agency compared to non-meditators, which may be linked to their higher bodily awareness and mindfulness (Cebolla et al., 2016; Khoury et al., 2023; Michalak et al., 2012; Nave et al., 2021). The current study combined state-of-the-art meditation research on bodily awareness (Nave et al., 2021; Trautwein et al., 2024) with the multisensory embodiment of an avatar in VR (Bayer et al., 2023; Cebolla et al., 2019; Ehrsson, 2007; Noel et al., 2015; Salomon et al., 2016) to design a meditation practice aimed at cultivating self-compassion. By embodying the avatar in the present meditation, participants increased their perspective-taking ability and their self-compassion scores. Future studies are needed to explicitly test whether embodying the avatar would also increase empathy per se. This would be expected based on a previous study showing that individuals with higher empathy levels performed better in perspective-taking (Heydrich et al., 2021). Moreover, empathy has also been suggested as a precursor for cultivating compassion in meditation (Luberto et al., 2018) and that higher levels of empathy may foster greater compassion (Ashar et al., 2016). As empathy for suffering others can lead to personal distress or compassion (Singer & Klimecki, 2014), future studies are needed to test how the current practice affects personal distress, which can lead to burnout, and compassion, which promotes resilience (Klimecki et al., 2013). Moreover, our approach aligns with traditional practices for transforming empathy into compassion, which emphasizes the importance of understanding another person's perspective while maintaining one's own (Preckel et al., 2018; Quesque et al., 2024). By embodying the avatar in our meditation design while maintaining one's own first-person perspective, we developed a meditation practice that could contribute to cultivating empathy, for oneself and for others, which we have not tested here. We note that we report transient changes of self-compassion scores following a single session of meditation (i.e. potential changes may have disappeared by the time the questionnaire-based measurements were taken, because the avatar was no longer present). Future studies should test the effects of multiple ASC sessions and ask participants to fill reports while sitting in VR with the avatar still present. Similar to the induced changes in brain plasticity by long-term meditation (Tang et al., 2019; Zsadanyi et al., 2021), the repeated exposure to the current ASC meditation or future adaptations (see above), hold the potential to bring about long-term subjective and behavioral effects that can be supported by personalized adaptations of the avatar (i.e., distance, orientation, body position, visual characteristics). Notably, previous VR designs that embodied the avatar without meditation guidance also reported improved self-compassion scores (Falconer et al., 2014, 2016), suggesting that VR-based self-compassion meditation holds promise even without guided audio components.

Limitations and Future Directions

While we compared the ASC condition—guided self-compassion meditation in VR—with a standard eyes-closed self-compassion meditation (SSC) to evaluate the potential benefits of the VR-based approach, we acknowledge several differences between conditions. Specifically, differences between eyes-open and eyes-closed states can lead to distinct behavioral and neural responses (Pradeep Kumar et al., 2023), which may have influenced our main comparison. Moreover, the presence or absence of the VR environment itself could further contribute to these differences. Future studies should investigate both self-compassion conditions in VR (i.e., two or more different forms of ASC conditions in VR with eyes open). Second, the pixelated animation of the avatar may have degraded the quality of participants' co-perception of their body and avatar, hence limiting the self-identification with and perspective-taking toward the avatar. Future work could also integrate and track a real-physical mirror in VR or compare VR to a real mirror, as meditation practices have shown that one's mirror reflection may aid the cultivation of self-compassion (Freysteinson, 2020; Petrocchi et al., 2017). Another limitation of the present study is the absence of a measure assessing participants' identification with the self-avatar. Future research should directly measure self-identification with the avatar after ASC, for example by using the full-body illusion (i.e., Lenggenhager et al., 2007; Noel et al., 2015) or the enfacement illusion (Porciello et al., 2018; Tajadura-Jiménez et al., 2012), which would help clarify how individual differences in bodily self-consciousness (i.e. Blanke et al., 2015) relate to self-compassion. Additionally, the current findings do not establish an additional emotional benefit from the embodied process. Accordingly, the practical advantage of the VR setup over a simpler audio-guided version remains to be determined.

The dissociation between OBT and State Self-Compassion Scale scores suggests that changes in embodied perspective-taking and subjective compassion outcomes may differ in temporal sensitivity. A 17-min intervention may have been sufficient to increase self-compassion in both conditions relative to baseline, leaving limited room for additional differences between conditions, whereas performance in the OBT may have been more sensitive to the avatar-related embodiment manipulation, which may directly train the capacity for bodily perspective taking.

Although the sample size ($n = 26$) may appear modest, the study was planned using a priori power analysis based on the best available effect-size estimates from prior research (Blanke et al., 2005). The within-subject design provides greater sensitivity than a between-subjects design by reducing inter-individual variability, although it does not eliminate potential sequence-related influences such as fatigue, practice, or residual emotional states. At the same time, the reference effect sizes were drawn from studies that differed from the present comparison and may have overestimated the effect expected between two active self-compassion conditions. Accordingly, the null findings on the self-compassion scales should be interpreted cautiously, as smaller or more subtle between-condition effects may have remained undetected and should be examined in future studies with larger samples.

The present study did not include long-term follow-up assessments; therefore, it remains unclear whether the observed effects persist beyond the immediate post-meditation period. In addition, the study was conducted in a highly controlled experimental VR setting using specialized procedures, which may limit generalizability to more naturalistic contemplative or clinical contexts. Similar to the brain plasticity changes associated with long-term meditation practice (Tang et al., 2019; Zsadanyi et al., 2021), repeated exposure to the current ASC meditation, as well as future adaptations of the paradigm, may have the potential to produce longer-term subjective and behavioral effects. Such effects may be further supported by personalized adaptations of the avatar (e.g., distance, orientation, body position, and visual characteristics). It is also important to note that self-compassion is typically cultivated through repeated practice, rather than through a single session of brief exercise (Tang, 2017). Accordingly, the present findings concern the short-term state-level changes following one meditation session and should not be interpreted as evidence regarding longer-term trait-level cultivation of self-compassion.

From a practical perspective, avatar-based VR may be useful as a research platform for experimentally manipulating embodied self-representation during compassion practice. Clinically, such approaches may eventually prove helpful for individuals who have difficulty engaging with self-directed compassion through conventional formats alone. However, given the preliminary design and the similar degree of the increase in self-compassion compared to the baseline, these implications remain provisional and require further testing in VR technology that is adapted to the clinical setting.

In summary, this study showed that self-compassion can be cultivated and supported by a VR-based approach that combines an avatar of the participant in cardio-visual synchrony with audio-guided self-compassion meditation. Compared to baseline, the ASC and SSC meditations elicited higher self-compassion ratings, accompanied by improvements in both negative and positive mental states. Notably, ASC meditation improved our participants' perspective-taking ability compared to SSC meditation, suggesting its potential for enhancing perspective-taking and imagined empathetic engagement towards oneself, while cultivating deeper levels of self-compassion. Our study leveraged a VR-supported meditation platform to uncover new links between the sense of self and self-compassion, as evidenced by both subjective experiences and behavioral outcomes. Future studies should refine the integration of traditional self-compassion practices with VR to explore the brain mechanisms underlying the bodily self during meditation.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12671-026-02941-4.

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Loup Vuarnesson: Methodology, Software, Visualization, Writing - review and editing;

Diego Hangartner: Methodology;

Olga Klimecki: Writing - review and editing;

Olaf Blanke: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing - review and editing

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Data Availability The data of this study will be made available on reasonable request from the corresponding author.

Declarations

Ethics Approval The study was conducted in accordance with the Declaration of Helsinki, and approved by the Swiss Ethics Committees on research involving humans (Project ID: 2021–00358).

Informed Consent Informed consent was obtained from all individual participants prior to the experiment.

Conflict of interest The authors declare no competing interests.

Use of Artificial Intelligence AI was used for editing the manuscript to improve English language.

References

Albert, L., Lance, F., Dubessy, M., Herbelin, B., Reymond, G., & Blanke, O. (2019, October 22). *Real-time 360 body scanning system for virtual reality research applications*. Proc. of 3DBODY.TECH 2019 - 10th Int. Conference and Exhibition on 3D Body Scanning and Processing Technologies, Lugano, Switzerland, 22–23 Oct. 2019. https://doi.org/10.15221/19.150

Arzy, S., Thut, G., Mohr, C., Michel, C. M., & Blanke, O. (2006). Neural basis of embodiment: Distinct contributions of temporoparietal junction and extrastriate body area. *The Journal of Neuroscience, 26*(31), 8074–8081. https://doi.org/10.1523/JNEUROSCI.0745-06.2006

Ashar, Y. K., Andrews-Hanna, J. R., Yarkoni, T., Sills, J., Halifax, J., Dimidjian, S., & Wager, T. D. (2016). Effects of compassion meditation on a psychological model of charitable donation. *Emotion, 16*(5), 691–705. https://doi.org/10.1037/emo0000119

Aspell, J. E., Heydrich, L., Marillier, G., Lavanchy, T., Herbelin, B., & Blanke, O. (2013). Turning body and self inside out: Visualized heartbeats alter bodily self-consciousness and tactile perception. *Psychological Science, 24*(12), 2445–2453. https://doi.org/10.1177/0956797613498395

Banakou, D., Hanumanthu, P. D., & Slater, M. (2016). Virtual embodiment of white people in a black virtual body leads to a sustained reduction in their implicit racial bias. *Frontiers in Human Neuroscience*, *10*. https://doi.org/10.3389/fnhum.2016.00601

Batson, C. D., Early, S., & Salvarani, G. (1997). Perspective taking: Imagining how another feels versus imaging how you would feel. *Personality and Social Psychology Bulletin, 23*(7), 751–758. https://doi.org/10.1177/0146167297237008

Bayer, M., Betka, S., Herbelin, B., Blanke, O., & Zimmermann, E. (2023). The full-body illusion changes visual depth perception. *Scientific Reports, 13*(1), Article 1. https://doi.org/10.1038/s41598-023-37715-8

Bedford, F. L. (2012). A perception theory in mind–body medicine: Guided imagery and mindful meditation as cross-modal adaptation. *Psychonomic Bulletin & Review, 19*(1), 24–45. https://doi.org/10.3758/s13423-011-0166-x

Betka, S., Canzoneri, E., Adler, D., Herbelin, B., Bello-Ruiz, J., Kannape, O. A., Similowski, T., & Blanke, O. (2020). Mechanisms of the breathing contribution to bodily self-consciousness in healthy humans: Lessons from machine-assisted breathing? *Psychophysiology, 57*(8), Article e13564. https://doi.org/10.1111/psyp.13564

Bibeau, M., Dionne, F., & Leblanc, J. (2016). Can compassion meditation contribute to the development of psychotherapists' empathy? A review. *Mindfulness, 7*(1), 255–263. https://doi.org/10.1007/s12671-015-0439-y

Biran, A., & Jeremic, A. (2023). The feasibility of human identification from multiple ECGs using maximal overlap discrete wavelet transform (MODWT) and weighted majority voting method (WMVM). *Digital Medicine and Healthcare Technology*, *2*. https://doi.org/10.5772/dmht.13

Blanke, O., Mohr, C., Michel, C. M., Pascual-Leone, A., Brugger, P., Seeck, M., Landis, T., & Thut, G. (2005). Linking out-of-body experience and self processing to mental own-body imagery at the temporoparietal junction. *Journal of Neuroscience, 25*(3), 550–557. https://doi.org/10.1523/JNEUROSCI.2612-04.2005

Blanke, O., Slater, M., & Serino, A. (2015). Behavioral, neural, and computational principles of bodily self-consciousness. *Neuron, 88*(1), 145–166. https://doi.org/10.1016/j.neuron.2015.09.029

Blefari, M. L., Martuzzi, R., Salomon, R., Bello-Ruiz, J., Herbelin, B., Serino, A., & Blanke, O. (2017). Bilateral Rolandic operculum processing underlying heartbeat awareness reflects changes in bodily self-consciousness. *European Journal of Neuroscience, 45*(10), 1300–1312. https://doi.org/10.1111/ejn.13567

Campos, D., Cebolla, A., Quero, S., Bretón-López, J., Botella, C., Soler, J., García-Campayo, J., Demarzo, M., & Baños, R. M. (2016). Meditation and happiness: Mindfulness and self-compassion may mediate the meditation–happiness relationship. *Personality and Individual Differences, Individual Differences in Mindfulness, 93*, 80–85. https://doi.org/10.1016/j.paid.2015.08.040

Cebolla, A., Miragall, M., Palomo, P., Llorens, R., Soler, J., Demarzo, M., García-Campayo, J., & Baños, R. M. (2016). Embodiment and body awareness in meditators. *Mindfulness, 7*(6), 1297–1305. https://doi.org/10.1007/s12671-016-0569-x

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,* Article 1521. https://doi.org/10.3389/fpsyg.2019.01521

Chen, P., Wang, G., Ma, R., Jing, F., Zhang, Y., Wang, Y., Zhang, P., Niu, C., & Zhang, X. (2016). Multidimensional assessment of empathic abilities in patients with insular glioma. *Cognitive, Affective, & Behavioral Neuroscience, 16*(5), 962–975. https://doi.org/10.3758/s13415-016-0445-0

Cho, H., & Eo, S.-H. (2016). Outlier Detection for Mass Spectrometric Data. In K. Jung (Ed.), Statistical Analysis in Proteomics (pp. 91–102). Springer. https://doi.org/10.1007/978-1-4939-3106-4_5

Cigolla, F., & Brown, D. (2011). A way of being: Bringing mindfulness into individual therapy. *Psychotherapy Research, 21*(6), 709–721. https://doi.org/10.1080/10503307.2011.613076

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences, 19*(9), 515–523. https://doi.org/10.1016/j.tics.2015.07.001

Damasio, A. R. (1999). How the brain creates the mind. *Scientific American, 281*(6), 112–117. https://doi.org/10.1038/scientificamerican1299-112

Dash, Ch. S. K., Behera, A. K., Dehuri, S., & Ghosh, A. (2023). An outliers detection and elimination framework in classification task of data mining. *Decision Analytics Journal, 6*, 100164. https://doi.org/10.1016/j.dajour.2023.100164

Davidson, R. J., & Kaszniak, A. W. (2015). Conceptual and methodological issues in research on mindfulness and meditation. *American Psychologist, 70*(7), 581–592. https://doi.org/10.1037/a0039512

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews, 3*(2), 71–100. https://doi.org/10.1177/1534582304267187

Edwards, D. J., McEnteggart, C., Barnes-Holmes, Y., Lowe, R., Evans, N., & Vilardaga, R. (2017). The impact of mindfulness and perspective-taking on implicit associations toward the elderly: A relational frame theory account. *Mindfulness, 8*(6), 1615–1622. https://doi.org/10.1007/s12671-017-0734-x

Ehrsson, H. H. (2007). The experimental induction of out-of-body experiences. *Science, 317*, 1048-1048. https://doi.org/10.1126/science.1142175

Ehrsson, H. H., Wiech, K., Weiskopf, N., Dolan, R. J., & Passingham, R. E. (2007). Threatening a rubber hand that you feel is yours elicits a cortical anxiety response. *Proceedings of the National Academy of Sciences of the United States of America, 104*(23), 9828–9833. https://doi.org/10.1073/pnas.0610011104

Falconer, C. J., Slater, M., Rovira, A., King, J. A., Gilbert, P., Antley, A., & Brewin, C. R. (2014). Embodying compassion: A virtual reality paradigm for overcoming excessive self-criticism. *PLoS ONE, 9*(11), Article e111933. https://doi.org/10.1371/journal.pone.0111933

Falconer, C. J., Rovira, A., King, J. A., Gilbert, P., Antley, A., Fearon, P., Ralph, N., Slater, M., & Brewin, C. R. (2016). Embodying self-compassion within virtual reality and its effects on patients with depression. *Bjpsych Open, 2*(1), 74–80. https://doi.org/10.1192/bjpo.bp.115.002147

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Freysteinson, W. M. (2020). Demystifying the mirror taboo: A neurocognitive model of viewing self in the mirror. *Nursing Inquiry, 27*(4), Article e12351. https://doi.org/10.1111/nin.12351

Gallagher, S. (2000). Philosophical conceptions of the self: Implications for cognitive science. *Trends in Cognitive Sciences, 4*(1), 14–21. https://doi.org/10.1016/S1364-6613(99)01417-5

Gilbert, P., & Procter, S. (2006). Compassionate mind training for people with high shame and self-criticism: Overview and pilot study of a group therapy approach. *Clinical Psychology & Psychotherapy, 13*(6), 353–379. https://doi.org/10.1002/cpp.507

Goetz, J. L., Keltner, D., & Simon-Thomas, E. (2010). Compassion: An evolutionary analysis and empirical review. *Psychological Bulletin, 136*(3), 351–374. https://doi.org/10.1037/a0018807

Green, A. A., & Kinchen, E. V. (2021). The effects of mindfulness meditation on stress and burnout in nurses. *Journal of Holistic Nursing, 39*(4), 356–368. https://doi.org/10.1177/08980101211015818

Gundel, F., Von Spee, J., Schneider, S., Haeussinger, F. B., Hautzinger, M., Erb, M., Fallgatter, A. J., & Ehlis, A.-C. (2018). Meditation and the brain – Neuronal correlates of mindfulness as assessed with near-infrared spectroscopy. *Psychiatry Research: Neuroimaging, 271*, 24–33. https://doi.org/10.1016/j.pscychresns.2017.04.002

Heydrich, L., Aspell, J. E., Marillier, G., Lavanchy, T., Herbelin, B., & Blanke, O. (2018). Cardio-visual full body illusion alters bodily self-consciousness and tactile processing in somatosensory cortex. *Scientific Reports, 8*(1), Article 9230. https://doi.org/10.1038/s41598-018-27698-2

Heydrich, L., Walker, F., Blättler, L., Herbelin, B., Blanke, O., & Aspell, J. E. (2021). Interoception and empathy impact perspective taking. *Frontiers in Psychology*, *11,* Article 599429. https://doi.org/10.3389/fpsyg.2020.599429

Ionta, S., Heydrich, L., Lenggenhager, B., Mouthon, M., Fornari, E., Chapuis, D., Gassert, R., & Blanke, O. (2011). Multisensory mechanisms in temporo-parietal cortex support self-location and first-person perspective. *Neuron, 70*(2), 363–374. https://doi.org/10.1016/j.neuron.2011.03.009

Ionta, S., Perruchoud, D., Draganski, B., & Blanke, O. (2012). Body context and posture affect mental imagery of hands. *PLoS ONE, 7*(3), Article e34382. https://doi.org/10.1371/journal.pone.0034382

Ionta, S., Sforza, A., Funato, M., & Blanke, O. (2013). Anatomically plausible illusory posture affects mental rotation of body parts. *Cognitive, Affective, & Behavioral Neuroscience, 13*(1), 197–209. https://doi.org/10.3758/s13415-012-0120-z

Ionta, S., Martuzzi, R., Salomon, R., & Blanke, O. (2014). The brain network reflecting bodily self-consciousness: A functional connectivity study. *Social Cognitive and Affective Neuroscience, 9*(12), 1904–1913. https://doi.org/10.1093/scan/nst185

Kang, Y., & Falk, E. B. (2020). Neural mechanisms of attitude change toward stigmatized individuals: Temporoparietal junction activity predicts bias reduction. *Mindfulness, 11*(6), 1378–1389. https://doi.org/10.1007/s12671-020-01357-y

Khoury, B., Vergara, R. C., Sadowski, I., & Spinelli, C. (2023). Embodied mindfulness questionnaire: Scale development and validation. *Assessment, 30*(2), 458–483. https://doi.org/10.1177/10731911211059856

Klimecki, O. M., & Singer, T. (2017). The compassionate brain. In E. M. Seppälä, E. Simon-Thomas, S. L. Brown, M. C. Worline, C. D. Cameron, & J. R. Doty (Eds.), *The Oxford handbook of* *compassion science* (Vol. Vol. 1, pp. 109–120). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190464684.013.9

Klimecki, O. M., Leiberg, S., Lamm, C., & Singer, T. (2013). Functional neural plasticity and associated changes in positive affect after compassion training. *Cerebral Cortex, 23*(7), 1552–1561. https://doi.org/10.1093/cercor/bhs142

Klimecki, O. M., Leiberg, S., Ricard, M., & Singer, T. (2014). Differential pattern of functional brain plasticity after compassion and empathy training. *Social Cognitive and Affective Neuroscience, 9*(6), 873–879. https://doi.org/10.1093/scan/nst060

Kozhevnikov, M., Louchakova, O., Josipovic, Z., & Motes, M. A. (2009). The enhancement of visuospatial processing efficiency through Buddhist deity meditation. *Psychological Science, 20*(5), 645–653. https://doi.org/10.1111/j.1467-9280.2009.02345.x

Kraus, S., & Sears, S. (2009). Measuring the immeasurables: Development and initial validation of the self-other four immeasurables (SOFI) scale based on Buddhist teachings on loving kindness, compassion, joy, and equanimity. *Social Indicators Research, 92*(1), 169–181. https://doi.org/10.1007/s11205-008-9300-1

Lanzaro, C., Carvalho, S. A., Lapa, T. A., Valentim, A., & Gago, B. (2021). A systematic review of self-compassion in chronic pain: From correlation to efficacy. *The Spanish Journal of Psychology, 24*, Article e26. https://doi.org/10.1017/SJP.2021.22

Legrand, D., & Ruby, P. (2009). What is self-specific? Theoretical investigation and critical review of neuroimaging results. *Psychological Review, 116*(1), 252–282. https://doi.org/10.1037/a0014172

Lenggenhager, B., Tadi, T., Metzinger, T., & Blanke, O. (2007). Video ergo sum: Manipulating bodily self-consciousness. *Science, 317*(5841), 1096–1099. https://doi.org/10.1126/science.1143439

Logie, K., & Frewen, P. (2015). Self/other referential processing following mindfulness and loving-kindness meditation. *Mindfulness, 6*(4), 778–787. https://doi.org/10.1007/s12671-014-0317-z

Luberto, C. M., Shinday, N., Song, R., Philpotts, L. L., Park, E. R., Fricchione, G. L., & Yeh, G. Y. (2018). A systematic review and meta-analysis of the effects of meditation on empathy, compassion, and prosocial behaviors. *Mindfulness, 9*(3), 708–724. https://doi.org/10.1007/s12671-017-0841-8

Lutz, A., Brefczynski-Lewis, J., Johnstone, T., & Davidson, R. J. (2008). Regulation of the neural circuitry of emotion by compassion meditation: Effects of meditative expertise. *PLoS ONE, 3*(3), Article e1897. https://doi.org/10.1371/journal.pone.0001897

Marshall, S. L., Ciarrochi, J., Parker, P. D., & Sahdra, B. K. (2020). Is self-compassion selfish? The development of self-compassion, empathy, and prosocial behavior in adolescence. *Journal of Research on Adolescence, 30*(S2), 472–484. https://doi.org/10.1111/jora.12492

Martin-Allan, J., Leeson, P., & Lovegrove, W. (2021). The effect of mindfulness and compassion meditation on state empathy and emotion. *Mindfulness, 12*(7), 1768–1778. https://doi.org/10.1007/s12671-021-01639-z

Michalak, J., Burg, J., & Heidenreich, T. (2012). Don't forget your body: Mindfulness, embodiment, and the treatment of depression. *Mindfulness, 3*(3), 190–199. https://doi.org/10.1007/s12671-012-0107-4

Millière, R., Carhart-Harris, R. L., Roseman, L., Trautwein, F.-M., & Berkovich-Ohana, A. (2018). Psychedelics, meditation, and self-consciousness. *Frontiers in Psychology, 9,* Article 1475. https://doi.org/10.3389/fpsyg.2018.01475

Mohr, C., Rowe, A. C., & Blanke, O. (2010). The influence of sex and empathy on putting oneself in the shoes of others. *British Journal of Psychology, 101*(2), 277–291. https://doi.org/10.1348/000712609X457450

Navarrete, J., Campos, D., Diego-Pedro, R., González-Hernández, E., Herrero, R., Baños, R. M., & Cebolla, A. (2021). Compassion-based meditation quality practice and its impact on the positive attitudes toward others. *Mindfulness, 12*(8), 1940–1953. https://doi.org/10.1007/s12671-021-01652-2

Nave, O., Trautwein, F.-M., Ataria, Y., Dor-Ziderman, Y., Schweitzer, Y., Fulder, S., & Berkovich-Ohana, A. (2021). Self-boundary dissolution in meditation: A phenomenological investigation. *Brain Sciences, 11*(6), Article 819. https://doi.org/10.3390/brainsci11060819

Neff, K. D. (2003a). Self-compassion: An alternative conceptualization of a healthy attitude toward oneself. *Self and Identity, 2*(2), 85–101. https://doi.org/10.1080/15298860309032

Neff, K. D. (2003b). The development and validation of a scale to measure self-compassion. *Self and Identity, 2*(3), 223–250. https://doi.org/10.1080/15298860309027

Neff, K. D. (2016). The self-compassion scale is a valid and theoretically coherent measure of self-compassion. *Mindfulness, 7*(1), 264–274. https://doi.org/10.1007/s12671-015-0479-3

Neff, K. D., Whittaker, T. A., & Karl, A. (2017). Examining the factor structure of the self-compassion scale in four distinct populations: Is the use of a total scale score justified? *Journal of Personality Assessment, 99*(6), 596–607. https://doi.org/10.1080/00223891.2016.1269334

Noel, J.-P., Pfeiffer, C., Blanke, O., & Serino, A. (2015). Peripersonal space as the space of the bodily self. *Cognition, 144*, 49–57. https://doi.org/10.1016/j.cognition.2015.07.012

Northoff, G., Heinzel, A., De Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain—A meta-analysis of imaging studies on the self. *NeuroImage, 31*(1), 440–457. https://doi.org/10.1016/j.neuroimage.2005.12.002

Park, H.-D., Bernasconi, F., Salomon, R., Tallon-Baudry, C., Spinelli, L., Seeck, M., Schaller, K., & Blanke, O. (2018). Neural sources and underlying mechanisms of neural responses to heartbeats, and their role in bodily self-consciousness: An intracranial EEG study. *Cerebral Cortex, 28*(7), 2351–2364. https://doi.org/10.1093/cercor/bhx136

Parsons, L. M. (1987). Imagined spatial transformation of one's body. *Journal of Experimental Psychology: General, 116*(2), 172–191. https://doi.org/10.1037/0096-3445.116.2.172

Peck, T. C., Seinfeld, S., Aglioti, S. M., & Slater, M. (2013). Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition, 22*(3), 779–787. https://doi.org/10.1016/j.concog.2013.04.016

Petrocchi, N., Ottaviani, C., & Couyoumdjian, A. (2017). Compassion at the mirror: Exposure to a mirror increases the efficacy of a self-compassion manipulation in enhancing soothing positive affect and heart rate variability. *The Journal of Positive Psychology, 12*(6), 525–536. https://doi.org/10.1080/17439760.2016.1209544

Porciello, G., Bufalari, I., Minio-Paluello, I., Di Pace, E., & Aglioti, S. M. (2018). The 'enfacement' illusion: A window on the plasticity of the self. *Cortex, 104*, 261–275. https://doi.org/10.1016/j.cortex.2018.01.007

Pradeep Kumar, G., Sharma, K., Adarsh, A., Manvi, A., Ramajayam, G., & Ramakrishnan, A. G. (2023). Functional reorganization of the brain in distinct frequency bands during eyes-open meditation. *Consciousness and Cognition, 116*, Article 103590. https://doi.org/10.1016/j.concog.2023.103590

Preckel, K., Kanske, P., & Singer, T. (2018). On the interaction of social affect and cognition: Empathy, compassion and theory of mind. *Current Opinion in Behavioral Sciences, Emotion-Cognition Interactions, 19*, 1–6. https://doi.org/10.1016/j.cobeha.2017.07.010

Preston, C., Kuper-Smith, B. J., & Ehrsson, H. H. (2015). Owning the body in the mirror: The effect of visual perspective and mirror view on the full-body illusion. *Scientific Reports, 5*(1), Article 18345. https://doi.org/10.1038/srep18345

Quesque, F., Apperly, I., Baillargeon, R., Baron-Cohen, S., Becchio, C., Bekkering, H., Bernstein, D., Bertoux, M., Bird, G., Bukowski, H., Burgmer, P., Carruthers, P., Catmur, C., Dziobek, I., Epley, N., Erle, T. M., Frith, C., Frith, U., Galang, C. M., … Brass, M. (2024). Defining key concepts for mental state attribution. *Communications Psychology*, *2*(1), Article 29. https://doi.org/10.1038/s44271-024-00077-6

Salomon, R., Fernandez, N. B., Van Elk, M., Vachicouras, N., Sabatier, F., Tychinskaya, A., Llobera, J., & Blanke, O. (2016). Changing motor perception by sensorimotor conflicts and body ownership. *Scientific Reports, 6*(1), Article 25847. https://doi.org/10.1038/srep25847

Schmalzl, L., Thomke, E., Ragnö, C., Nilseryd, M., Stockselius, A., & Ehrsson, H. H. (2011). "Pulling telescoped phantoms out of the stump": Manipulating the perceived position of phantom limbs using a full-body illusion. *Frontiers in Human Neuroscience*, *5,* Article 121. https://doi.org/10.3389/fnhum.2011.00121

Schwabe, L., Lenggenhager, B., & Blanke, O. (2009). The timing of temporoparietal and frontal activations during mental own body transformations from different visuospatial perspectives. *Human Brain Mapping, 30*(6), 1801–1812. https://doi.org/10.1002/hbm.20764

Serino, A., Noel, J.-P., Galli, G., Canzoneri, E., Marmaroli, P., Lissek, H., & Blanke, O. (2015). Body part-centered and full body-centered peripersonal space representations. *Scientific Reports, 5*(1), Article 18603. https://doi.org/10.1038/srep18603

Seth, A. K., & Tsakiris, M. (2018). Being a beast machine: The somatic basis of selfhood. *Trends in Cognitive Sciences, 22*(11), 969–981. https://doi.org/10.1016/j.tics.2018.08.008

Singer, T., & Klimecki, O. M. (2014). Empathy and compassion. *Current Biology, 24*(18), R875–R878. https://doi.org/10.1016/j.cub.2014.06.054

Singer, T., & Lamm, C. (2009). The social neuroscience of empathy. *Annals of the New York Academy of Sciences, 1156*(1), 81–96. https://doi.org/10.1111/j.1749-6632.2009.04418.x

Singer, T., & Tusche, A. (2014). Understanding others: Brain mechanisms of theory of mind and empathy. *Neuroeconomics* (pp. 513–532). Academic Press. https://doi.org/10.1016/B978-0-12-416008-8.00027-9

Singer, T., Critchley, H. D., & Preuschoff, K. (2009). A common role of insula in feelings, empathy and uncertainty. *Trends in Cognitive Sciences, 13*(8), 334–340. https://doi.org/10.1016/j.tics.2009.05.001

Steffen, P. R., Foxx, J., Cattani, K., Alldredge, C., Austin, T., & Burlingame, G. M. (2021). Impact of a 12-Week Group-Based Compassion Focused Therapy Intervention on Heart Rate Variability. *Applied Psychophysiology and Biofeedback, 46*(1), 61–68. https://doi.org/10.1007/s10484-020-09487-8

Suzuki, K., Garfinkel, S. N., Critchley, H. D., & Seth, A. K. (2013). Multisensory integration across exteroceptive and interoceptive domains modulates self-experience in the rubber-hand illusion. *Neuropsychologia, 51*(13), 2909–2917. https://doi.org/10.1016/j.neuropsychologia.2013.08.014

Suzuki, Y., & Sakamoto, S. (2023). Development of the "belief of affective perspective-taking ability scale." *Psychological Reports, 126*(5), 2551–2563. https://doi.org/10.1177/00332941221075751

Tadi, T., Overney, L. S., & Blanke, O. (2009). Three sequential brain activations encode mental transformations of upright and inverted human bodies: A high resolution evoked potential study. *Neuroscience, 159*(4), 1316–1325. https://doi.org/10.1016/j.neuroscience.2009.02.012

Tajadura-Jiménez, A., Longo, M. R., Coleman, R., & Tsakiris, M. (2012). The person in the mirror: Using the enfacement illusion to investigate the experiential structure of self-identification. *Consciousness and Cognition, 21*(4), 1725–1738. https://doi.org/10.1016/j.concog.2012.10.004

Tang, Y.-Y. (2017). Traits and states in mindfulness meditation. *The Neuroscience of mindfulness meditation: How the body and mind work together to change our behaviour* (pp. 29–34). Springer International Publishing. https://doi.org/10.1007/978-3-319-46322-3_4

Tang, Y.-Y., Tang, R., Rothbart, M. K., & Posner, M. I. (2019). Frontal theta activity and white matter plasticity following mindfulness meditation. *Current Opinion in Psychology, Mindfulness, 28*, 294–297. https://doi.org/10.1016/j.copsyc.2019.04.004

Tholen, M. G., Trautwein, F.-M., Böckler, A., Singer, T., & Kanske, P. (2020). Functional magnetic resonance imaging (fMRI) item analysis of empathy and theory of mind. *Human Brain Mapping, 41*(10), 2611–2628. https://doi.org/10.1002/hbm.24966

Tomasino, B., Campanella, F., & Fabbro, F. (2016). Medial orbital gyrus modulation during spatial perspective changes: Pre- vs. post-8 weeks mindfulness meditation. *Consciousness and Cognition, 40*, 147–158. https://doi.org/10.1016/j.concog.2016.01.006

Trautwein, F.-M., Schweitzer, Y., Dor-Ziderman, Y., Nave, O., Ataria, Y., Fulder, S., & Berkovich-Ohana, A. (2024). Suspending the embodied self in meditation attenuates beta oscillations in the posterior medial cortex. *Journal of Neuroscience, 44*(26), Article e1182232024. https://doi.org/10.1523/JNEUROSCI.1182-23.2024

Tsakiris, M. (2017). The multisensory basis of the self: From body to identity to others. *Quarterly Journal of Experimental Psychology, 70*(4), 597–609. https://doi.org/10.1080/17470218.2016.1181768

Tusche, A., Böckler, A., Kanske, P., Trautwein, F.-M., & Singer, T. (2016). Decoding the charitable brain: Empathy, perspective taking, and attention shifts differentially predict altruistic giving. *Journal of Neuroscience, 36*(17), 4719–4732. https://doi.org/10.1523/JNEUROSCI.3392-15.2016

Vuarnesson, L., Herbelin, B., & Blanke, O. (2024). Virtual Reality for inward contemplation. *ACM SIGGRAPH 2024 Talks*, 1–2. https://doi.org/10.1145/3641233.3664341

Yang, H., Herbelin, B., Ngo, C., Vuarnesson, L., & Blanke, O. (2025). Meditation in the third-person perspective modulates minimal self and heartbeat-evoked potentials. *NeuroImage, 314*, Article 121265. https://doi.org/10.1016/j.neuroimage.2025.121265

Yela, J. R., Crego, A., Gómez-Martínez, M. Á., & Jiménez, L. (2020). Self-compassion, meaning in life, and experiential avoidance explain the relationship between meditation and positive mental health outcomes. *Journal of Clinical Psychology, 76*(9), 1631–1652. https://doi.org/10.1002/jclp.22932

Zacks, J., Rypma, B., Gabrieli, J. D. E., Tversky, B., & Glover, G. H. (1999). Imagined transformations of bodies: An fMRI investigation. *Neuropsychologia, 37*(9), 1029–1040. https://doi.org/10.1016/S0028-3932(99)00012-3

Zessin, U., Dickhäuser, O., & Garbade, S. (2015). The relationship between self-compassion and well-being: A meta-analysis. *Applied Psychology: Health and Well-Being, 7*(3), 340–364. https://doi.org/10.1111/aphw.12051

Zeugin, D., Notter, M. P., Knebel, J.-F., & Ionta, S. (2020). Temporoparietal contribution to the mental representations of self/other face. *Brain and Cognition, 143*, Article 105600. https://doi.org/10.1016/j.bandc.2020.105600

Zsadanyi, S. E., Kurth, F., & Luders, E. (2021). The effects of mindfulness and meditation on the cingulate cortex in the healthy human brain: A review. *Mindfulness, 12*(10), 2371–2387. https://doi.org/10.1007/s12671-021-01712-7