Virtual Body Swapping: A VR-Based Approach to Embodied Third-Person Self-Processing in Mind-Body Therapy

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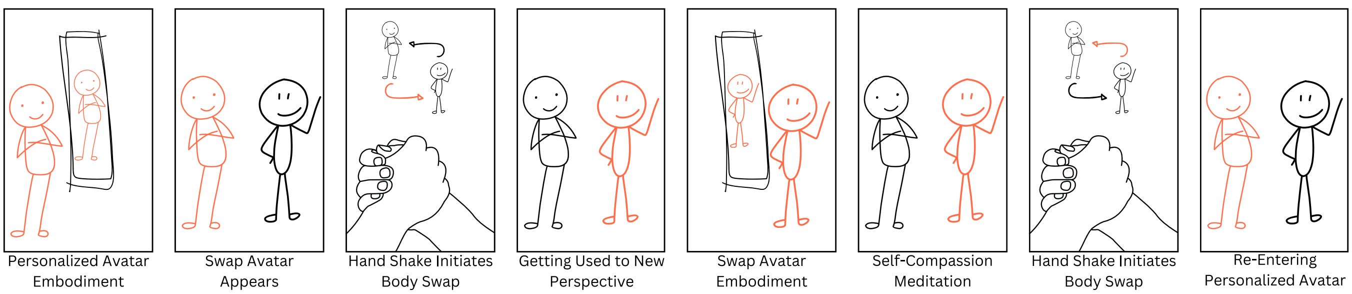

Figure 1: This figure shows the virtual body-swapping process used in our study. The orange color indicates which avatar is currently controlled by the participants.

ABSTRACT

Virtual reality (VR) offers various opportunities for innovative therapeutic approaches, especially regarding self-related mind-body interventions. We introduce a VR body swap system enabling multiple users to swap their perspectives and appearances and evaluate its effects on virtual sense of embodiment (SoE) and perception- and cognition-based self-related processes. In a self-compassion-framed scenario, twenty participants embodied their personalized, photorealistic avatar, swapped bodies with an unfamiliar peer, and reported their SoE, interoceptive awareness (perception), and self-compassion (cognition). Participants' experiences differed between bottom-up and top-down processes. Regarding SoE, their agency and self-location shifted to the swap avatar, while their top-down self-identification remained with their personalized avatar. Further, the experience positively affected interoceptive awareness but not self-compassion. Our outcomes offer novel insights into the SoE in a multiple-embodiment scenario and highlight the need to differentiate between the different processes in intervention design. They raise concerns and requirements for future research on avatar-based mind-body interventions.

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CCS CONCEPTS

• **Human-centered computing → Virtual reality**; *Laboratory experiments*; *Empirical studies in HCI*.

KEYWORDS

Virtual reality, embodiment, self-compassion, body awareness, body swap, perspective taking.

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1 INTRODUCTION

Virtual reality (VR) and avatars find increasing use in psychotherapeutic practices. VR systems offer diverse opportunities, encompassing presence in a virtual environment and facilitating diverse perspectives and the potential for embodying differently appearing virtual bodies. The exposure to such virtual bodies, avatars, can elicit a sense of embodiment (SoE) toward them, a feeling of incarnating it in the virtual environment [42]. Current studies on avatar-based SoE mainly involve users embodying a single avatar with a specific appearance. These studies investigate how the embodiment of and control over different-looking avatars affects the users' SoE [81], their relationship to their physical body [22, 53, 83], or other therapy-related outcomes [15, 27]. What unifies most of these studies is that they confront the user with a single avatar that either looks like themselves, is slightly altered, or differs significantly from the user's appearance. What has been explored less so far is what happens when users embody multiple avatars, either successively [27] or simultaneously [36], and how such a body swap affects self-perception in mind-body interventions.

Perspective shifts are frequently used in therapeutic scenarios [9, 35]. Patients create distance to themselves [43] by imaginary taking on a different perspective or taking different perspectives on a scene by role-playing with others. We present a VR system that allows body swapping in real-time. Users exchange their avatars and perspectives with other users by a handshake. The exchange partners can be in the same physical space or interact with each other remotely. In an evaluation study with personalized photorealistic avatars and a self-compassion meditation task, we investigate the following: (1) Does body swapping per se, and (2) does the visibility of the swap avatar affect the SoE towards one's personalized avatar and the swap avatar, interoceptive awareness, and self-compassion. We further qualitatively elaborated on the user experience during the body-swapping process.

Our contribution is twofold. We present a distributed body swap system allowing for real-time perspective switches. Additionally, we contribute new insights into the SoE toward personalized and generic avatars during a self-compassion-oriented body swap scenario and put them in the context of body perception. Virtual body swap experiences can be an innovative milestone for all interventions that work with perspective change. Therefore, we contribute groundbreaking results for such systems' effects and future design.

2 RELATED WORK

Increasing numbers of mental disorders, including those arising during and after the COVID-19 pandemic [16, 46], reinforce the demand for a range of intervention options beyond substance-oriented therapy. So-called mind-body interventions, in particular, are increasingly the focus of attention in treating mental disorders [73]. Mind-body interventions, also referred to as mind-body therapy, mindfulness-based therapy, or meditation-based interventions, are a broad field of therapy forms under the guise of connecting mind and body, creating conscious self-awareness, and increasing mindfulness [34, 77].

While mind-body interventions have not always been part of conventional medicine, in recent decades, more and more evidence of their efficacy in the treatment of mental disorders has emerged, making them an increasing part of the therapeutic landscape alongside traditional psychotherapy and drug-oriented medicine [77]. While some are rooted in ancient practices, most modern mind-body interventions are based on the philosophical approach of the theory of embodied cognition. Similar to approaches like somaesthetics by Shusterman [65] and somaesthetic design, which combines embodied cognition with aesthetics, they take a holistic approach to the design and structure of therapeutic exercises. They treat the body, the soma, both as a means of expression and as the basis of all perceptions and thoughts. Grounded in the relationship between mind, body, and behavior, these interventions aim to strengthen the positive effects between those [77]. While the specific methods are diverse, mind-body interventions usually include a combination of conscious physical movement exercises, mindfulness or meditation practices, and body-based attention exercises, including breathing techniques.

2.1 Mind- and Body-Oriented Self-Related Processes

How mind-body interventions affect therapeutical outcomes can be explained by self-related processes [12]. These processes can be roughly classified into three categories: pre-reflective embodied, cognitive-conceptual, and processes supporting self-regulation by combining perceptive and cognitive processing characteristics. Britton et al. [12] assign the self-related processes to a continuum between a more embodied "self as subject" and a more conceptual "self as object". The more body-oriented processes, including interoception, sense of agency, sense of body ownership, sense of boundaries, and perspectival self (or self-location), occur here under the umbrella of embodiment and align with the self as subject. The more cognitive or mind-related processes, including narrative self, self-criticism, self-compassion, self-evaluation, self-esteem, and rumination, occur under the conceptual self or self as object.

It is important to emphasize that framing embodiment as predominantly perceptual is not necessarily exhaustive. Embodiment, too, has been described as a dual experience of perceiving and being perceived, both as something that we are (being a body, the body as subject, similar to the self as subject) and that we own (having a body, the body as object, similar to the self as object) [41]. This understanding of embodiment aligns more with an alternative, body-centric description of the overall self-related processes. However, in this work, we adopt the definition of Britton et al. [12] to delineate different internal processes.

Mind-body interventions can positively modify a range of self-related processes and, in turn, affect their interrelation. How these self-related processes mediate between the respective intervention method and its therapeutic goal has yet to be thoroughly investigated. For some cognition-related processes, relationships have already been identified. Notably, reducing rumination is associated with improved outcomes for mental health. Other processes, such as self-compassion, have been indicated to have a positive relationship with well-being [12]. Concerning the more body-related processes, the available data is thinner.

However, while they do not necessarily explain the mediative role of embodied self-related processes, some studies highlight the effects of mind-body interventions on them. For example, Dambrun et al. [18] found an effect of mindfulness meditation practice on the sense of self-location. Hanley et al. [39] found a decreasing effect of meditation exercises on perceived body boundaries.

2.2 Taking Perspectives on the Self

One method to investigate the possible effects of embodied self-related processing on further outcomes is to transfer the experience to VR. VR allows us to experience the body in a new way by changes in appearance, body shape, and movement of an embodied avatar, changes in the perspective on the supposedly "own" avatar, and so on. Hence, various possibilities exist to impact body-related, perceptual self-related processes in VR.

Beyond VR-based meditation applications without visual body representations [24], the embodiment of virtual bodies, so-called avatars, as a possibility for self-reflection has been repeatedly proposed in recent years [17, 25, 58]. This includes exploring perspective changes or out-of-body simulations in VR, transitioning from a first-person perspective (1pp) of oneself to a third-person perspective (3pp) or another virtual character. For instance, Osimo et al. [58] and Slater et al. [66] investigated virtual self-counseling. Subjects switched perspectives between their virtual selves, an avatar designed to resemble them, and a virtual representation of Sigmund Freud. This body swap increased the perceived support of the conversation compared to swapping between two self-avatars or even a pre-scripted conversation with Sigmund Freud. The authors explain this effect by the distance gained by switching to the Freud avatar. However, they did not investigate whether a perceptual distance to self-perception had actually arisen, for example, through a change in self-location or interoception.

Falconer et al. [27] provide another example of virtual perspective in self-related processing. In a self-compassion exercise with depression patients, they investigated the effect of transitioning from an adult to a child avatar. Subjects reported increased self-compassion, reduced self-criticism, and reduced depression symptoms. However, no comparison was made to a condition without body swapping or between different embodiment conditions. In an augmented reality self-compassion exercise, Cebolla et al. [15] showed that shifting perspective to another person, gaining an outside view of one's body during a self-compassion meditation, affected subjects' interoception, self-compassion, and overall mindfulness, comparable to the results of a meditative imagination exercise. Finally, Landau [44] presented a method for virtual self-encounter and embodiment of another person via 360° videos. Based on a conference demonstration, they reported some positive effects, meaningful moments, and altered body perception.

As an interim conclusion, these first studies show the potential of body swapping for therapeutical aims. Past research has shown that the embodiment of an avatar can affect the user's experience and behavior. To fully understand how body swapping and the sequential embodiment of multiple avatars in VR contribute to the future of mind-body interventions, it is crucial to investigate the effects on therapy-relevant variables. However, measuring these target variables covers only part of the possible effects of a body swap scenario. Examining moderating variables is necessary to pinpoint what mechanisms might lie behind them. Following approaches to systematically investigate the relationship between specific VR-related behavior mechanisms and therapy-relevant measures [82], our work aims at two sets of variables. We investigate the effects of a body-swap scenario on self-related processes mediating mind-body interventions, both on a perceptual (e.g., interoception) and a cognitive layer (e.g., self-compassion). Additionally, we target gaining new insights into how users perceive the two sequentially embodied avatars, highlighting effects on the SoE. Finally, we combine these two sets of variables and examine how they are related.

2.3 Embodied Self-Related Processes in Virtual Body Swapping

2.3.1 Sense of Virtual Embodiment. The SoE can be deduced from embodied self-related processes and transfers them to the processing of avatars. SoE, too, differentiates between body ownership (sense of virtual body ownership, VBO), agency (sense of agency over the avatar), and perspectival self (sense of self-location in the avatar) [42]. Moreover, the SoE is often extended by further perceptual components, including self-attribution (the extent to which one finds oneself reflected in the avatar), change (the extent to which one feels that the avatar has an impact on the self), or self-similarity (the extent of similarity perceived between oneself and the avatar).

Various studies have investigated which factors enhance or reduce SoE [52, 81]. For example, the VBO is affected by the similarity between avatar and user, the degree of realism, and especially by personalization [62, 81]. Conversely, the sense of agency is influenced by the accuracy with which the avatar follows the user's movements or by the time spent in VR [52]. Regarding the perspective on the avatar, a 1pp seems to be more critical than a 3pp [20]. Prolonged mirror exposure does not consistently increase SoE [52]. Yet, confronting users with their mirror image during body movements is a common method to accustom them to their virtual appearance [68]. Considering a body swap's potential to stimulate higher-level self-related processes, it is reasonable to consider such events' influence on the perceptual level of self- and avatar-processing.

In the body-swapping studies cited above, the focus concerning the SoE was predominantly on the acutely controlled avatar. Studies examined whether participants experience a SoE toward a virtual Freud [58, 66], a virtual "inner child" [27], or the experimenter [15]. However, the avatar, which participants embody first, is introduced by appearance or framing as the current "self-avatar". It is, thus, thematically closer to the participants. Hence, it is crucial to consider how the relationship to this self-avatar changes through the body swap and how it potentially affects other self-related processes.

The impact of embodiment or exposure to two avatars simultaneously or in short successive intervals is part of the current research on SoE. For example, Guterstam et al. [36] reported a "dual full-body ownership illusion" and a "dual self-location" with proximate avatars presented from 1pp. Similarly, Verhulst et al. [78] observed parallel motor adaptation to two avatars controlled in short alternation, differing slightly in movements from the participants and each other. Other studies have used perspective changes on a single avatar [17, 31]. However, subjects in these studies retained control over the movements of the different avatars at all times, possibly limiting the association of external perspective change with distancing from the self-avatar. Additionally, most of these studies did not focus on self-related processes in a mind-body-oriented scenario. Building on the existing research, we pose four research questions regarding the SoE:

RQ 1.1: Does a virtual body swap affect SoE toward a personalized self-avatar?
RQ 1.2: Does the visibility of a swap avatar affect the SoE toward the personalized avatar?
RQ 1.3: Do participants experience SoE toward a non-personalized swap avatar while their personalized avatar is visible in the same virtual space?
RQ 1.4: In body swapping, how does the SoE toward a personalized avatar relate to self-related processes?

2.3.2 Interoception. Besides the self-related processes within SoE, interoception is already part of different investigations in avatar embodiment. Interoception involves processing and integrating signals from within the body. Originally centered on awareness of bodily needs, the subjective interpretation of bodily signals has come into focus over the last few years. According to a definition by Garfinkel et al. [32], different facets of interoception can be distinguished. On the one hand, interoceptive accuracy describes the accuracy with which physical signals can be detected. Interoceptive awareness is the subjective perception of being in contact with the body signals. Interoceptive sensibility is the subjective confidence regarding interoceptive accuracy. Regarding its therapeutic relevance, interoception is the most studied construct among the perceptual-oriented self-related processes [12]. Low interoception is frequently associated with symptoms for body image disorders [11, 13], but has also been shown to affect pain management [8, 19] or self-harm [86]. Among others, interoception is mentioned as a driver of mind-body interventions [59] or as a mediator for higher-cognitive self-related processes, including self-compassion [4].

A reciprocal relationship between interoception and embodiment processing with artificial or virtual bodies has been established several times. Individuals with high interoceptive accuracy are less willing to engage with an unfamiliar body and report lower VBO [29, 51, 63]. Conversely, compared to a real-world exercise, Döllinger et al. [22] reported that realistic avatar embodiment could negatively affect interoceptive awareness. However, within a virtual experience, an increased VBO towards an avatar has been associated with increased interoceptive accuracy [29] or increased interoceptive awareness [15, 23, 25]. Regardless of the measure, interoception during avatar or artificial body part embodiment is significantly affected by how an SoE is targeted. This is evident in studies of visuo-tactile congruence [29], in which interoception benefited from congruence. It also becomes apparent in studies of avatar appearance, in which anthropomorphism has been found to support interoception [50] .

So far, studies on the effects of the perspective of a personalized avatar on SoE and interoception have only added a virtual mirror [22] with little to no effect on interoception, besides a minor shift in focus toward the mirror image. However, simultaneously processing two avatars in a body-swapping scenario could distract from one's body. So far, it has yet to be investigated how the embodiment of two different avatars in a short sequence impacts interoception. Hence, in this work, we pose the following research questions:

RQ 2.1: Does a virtual body swap affect interoception?
RQ 2.2: Does the visibility of a swap avatar affect interoception?

2.4 Virtual Reality and Conceptual Self-Related Processes: Self-Compassion

One concept that appeals in the field of mind-body-oriented virtual perspective-taking is self-compassion. Self-compassion is defined as "openness to and compassion for one's suffering, feelings of caring and kindness toward oneself, an understanding, nonjudgmental attitude toward one's shortcomings and failures, and recognition that one's own experience is part of the general human experience" [54]. Mind-body interventions positively impact self-compassion [12]. While a positive effect of self-compassion in the clinical context has been inconsistently evidenced [12], self-compassion and self-compassion exercises are part of various current mind-body interventions [33, 45, 71].

Changing perspective into a caretaker or experimenter's point of view can increase self-compassion [15, 27]. Exploring the effects of a body swap starting from a personalized avatar can expand on these results. Additionally, whether swapping into a different avatar is beneficial or whether a simple outside perspective provides more support for self-compassion has yet to be investigated. In our work, we, therefore, address the following questions on self-compassion:

RQ 3.1: Does a virtual body swap affect self-compassion?
RQ 3.2: Does the visibility of a swap avatar affect self-compassion?

2.5 Contribution

We present a distributed multi-user system allowing real-time body swapping and using photorealistic personalized avatars to maximize user-avatar similarity. Our study focuses on the evaluation of this system. Twenty participants performed a virtual body swap, followed by a self-compassion meditation. The swap partner was an unfamiliar assistant experimenter. The swap avatar was either an invisible entity (de-embody) to reduce the processing expense of being confronted with two avatars or a gender-matched, unfamiliar peer (re-embody). The research question-guided evaluation aimed to determine the pre-post effects of body swapping (swap effect) and of swap avatar visibility (condition: de-embody vs. re-embody) on SoE towards the personalized and the swap avatar (RQ 1.1-1.3). We explored the relationship between SoE toward the personalized avatar and the two involved self-related processes, interoceptive awareness and self-compassion (RQ 1.4). We investigated the effects of the swap and condition on interoceptive awareness (RQ 2.1-2.2) and self-compassion (RQ 3.1-3.2). Finally, we used semi-structured qualitative interviews to investigate the user experience of the body swap, avatars, and VR exercises.

3 SYSTEM DESCRIPTION

3.1 Avatars

The avatars were generated following the methods outlined in the work by Bartl et al. [7] and a photorealistic avatar reconstruction pipeline similar to that introduced by Achenbach et al. [1]. We employed a custom multi-DSLR camera setup to capture photos of each

Figure 2: The female (left) and male (right) swap avatars used during the experiment.

Figure 3: The virtual environment.

angle of the participant simultaneously. These photos served as the basis for creating a dense point cloud representation of the participant's body using Agisoft Metashape [2]. Subsequently, we applied a fully rigged template mesh from Autodesk Character Generator [3] to fit onto the point cloud. on which we applied a fully rigged template mesh. Finally, a personalized photorealistic texture was generated, including the addition of generic hand textures to match the participant's characteristics. For the body swap, we created one female and one male avatar representing the swap partner using the same procedure. To ensure unfamiliarity between the participants and these swap avatars, we scanned two external volunteers who were neither involved in the design nor the execution of the study. The two avatars are shown in Figure 2.

3.2 Virtual Environment

The virtual environment consisted in a virtual room spanning $4\,m \times 6\,m$ that was adapted from a Unity asset[1]. It is depicted in Figure 3. For certain tasks, a $1\,m \times 2\,m$ mirror was placed on the wall, accompanied by a whiteboard positioned to the right or left of the mirror, matching the participant's location. A circular marker on the floor indicated the participant's starting point at a distance of 1.5 m of the virtual mirror. As the experiment progressed, footprints on the left and right of the circular markers indicated the designated position for the body-swap interaction at a distance of 1.5 m to each other.

3.3 Hardware and Software

The VR system consisted of two Valve Index Head-Mounted Displays (HMD) [75] and two sets of Valve Index controllers (Knuckles; see Figure 4). Three SteamVR Base Stations 2.0 tracked all devices. The cable-bound HMDs provided a resolution of $1440\,px \times 1600\,px$ per eye, a refresh rate of 144 Hz, and a total field of view of $109.4^{\circ} \times 114.1^{\circ}$[2]. The VR setup included two high-end gaming PCs (NVIDIA GeForce RTX 2080 Ti, 32 GB RAM, Intel Core i7-9700K CPU, and Windows 10), running the participant's and the swap partner's VR environment. The VR experience was implemented using Unity (version 2020.3.25f1 LTS) [74] and integrated the VR system using SteamVR [76] and its corresponding Unity plug-in (version 2.6.1)[3].

Our application facilitates the embodiment of two avatars by two users within a shared virtual environment. We employed a client-server architecture for networking functionality, utilizing Photon Unity Networking[4] (version 2.40). A remote server instance operated at the University of Applied Science (HTW) Berlin, enabling seamless data transmission over a high-speed internet connection. At the University of Würzburg, two distinct workstations ran individual client application instances, each integrating one HMD. Each user's pre-processed avatar pose was promptly displayed within the local application instance and continuously streamed to the remote user's application instance with a refresh rate of 30 Hz. Modifications to application settings were shared between both instances, ensuring a synchronized shared virtual environment.

For body tracking, we used Captury's markerless tracking system [14, 69], employing eight FLIR Blackfly S BFS-PGE-16S2C RGB cameras attached to the laboratory ceiling to track participant's movements at a rate of 100 Hz. The cameras were connected to a powerful workstation (NVIDIA GeForce RTX 3080 Ti, 32 GB RAM, AMD Ryzen 9 5900x, Ubuntu 20.04.6 LTS) running Captury Live (version 248). The participant's fingers were tracked via the proximity sensors of the Knuckles. The body poses of the participant and the swap partner were continuously streamed to the VR system using a 1 GBit/s ethernet connection and integrated using Captury's Unity plug-in[5] [84]. Afterward, we retargeted the received body pose to the corresponding avatar. We merged it with the remaining tracking data from the VR system using Unity's avatar animation system and a custom-written retargeting script. We matched the avatars' hand movements to those captured by the Knuckles for increased stability and accuracy in the hand poses. Accordingly, a participant's hand movements were delivered to their HMD with

[1]https://assetstore.unity.com/packages/3d/props/interior/manager-office-interior-107709
[2]https://github.com/PeterTh/ovr_rawprojection
[3]https://assetstore.unity.com/packages/tools/integration/steamvr-plugin-32647
[4]https://www.photonengine.com/pun
[5]https://captury.com/resources/

Figure 4: Handshake initiating body swap: Participant and their swap partner (left), participant avatar, and swap avatar in VR (right).

a motion-to-photon latency of 27 ms, aligning with the results of Warburton et al. [80]. The other body movements, captured by the markerless tracking, had a latency of 116 ms. Due to the server transmission, the movements of the swap partner were transmitted to the participant HMD with a latency increase of 66 ms. For comparison, the hand movements of the exchange partner were transmitted to the participant HMD with a latency of 93 ms.

3.4 Body Swap

The body swap included four steps: initiation, avatar swap, recalibration, and finalization. A handshake triggered the initiation as a shared consent gesture (Figure 4). Unity collider components attached to the avatars' hands facilitated collision detection to identify when the avatars' hands made contact. Upon handshake detection, a virtual loading bar appeared above the locked hands of the two users. The loading bar persisted for a three-second interval, visualizing the process state and allowing the users to prepare for the body swap. Releasing the handshake aborted the body swap and disabled the process bar. For the avatar swap, upon completing the handshake, a remote procedure call facilitated the body swap while both HMDs temporarily turned black. Each application instance changed the local user's self-avatar to correspond to the remote user's initial avatar. Both avatars were available on both local systems and were matched by unique avatar identifiers.

In the re-calibration phase, the local users' position and orientation within the virtual environment were adjusted to match the remote user's view. Therefore, each user's local tracking origin was rotated and translated, creating the illusion that they had swapped positions in the virtual environment, even though their physical bodies had not moved. Afterward, the primary experimenter re-calibrated the avatar retargeting on both local systems. For finalization, the HMDs were turned back on. The users now experienced the virtual environment from the other user's initial perspective while controlling the other user's avatar. Figure 5 depicts a participant's point of view during the body swap. The users could undo the body swap by initiating a second body swap, which followed the same procedure.

4 EVALUATION

4.1 Study Design

The study was carried out in a 2×2 mixed design. All participants started by embodying their personalized avatar before the body swap. Within each session, we assessed the SoE toward this avatar and the other dependent variables once before and once after the body swap (factor 1: pre-post swap effect). We varied between participants (factor 2: condition) whether they swapped into a visible swap avatar (re-embody) or whether they did not enter into a visible avatar in that process (de-embody). As dependent variables, we assessed the SoE towards their personalized avatars, interoceptive awareness, and self-compassion before and after the experience. We further assessed their SoE towards the swap avatar once after the body swap.

4.2 Participants

The study was conducted according to the Declaration of Helsinki and was approved by the ethics review board of the Institute Human-Computer-Media (MCM), University of Würzburg,[6]. Participants were recruited via the university's recruitment portal and received course credits in return. We excluded individuals in advance when (1) they had increased photosensitivity, (2) they felt uncomfortable with the idea of another person embodying their personalized avatar, (3) they had visual impairments that could not be corrected during the experiment, and (4) they were in any way familiar with the human model of their swap avatar. Overall, $N = 22$ individuals participated in our study, of which we had to exclude two due to technical problems. In the re-embody condition ($n = 10$), the age ranged between 20 and 32 years, $M = 22.90$ ($SD = 3.14$), with seven female and three male participants. In the de-embody condition ($n = 10$), the age ranged between 18 and 30 years, $M = 23.00$ ($SD = 3.58$), with six female and four male participants.

4.3 Measures

4.3.1 Avatar Perception. We assessed the SoE toward the self-avatar post-VR. Here, we used the Virtual Embodiment Questionnaire, VEQ [61], which provides 12 scales on three dimensions: VBO, agency, and change. The scales are presented on a 7-point Likert scale from 1 to 7. We added the scales proposed by Fiedler et al. [28], VEQ+, which pose 12 scales on three dimensions: self-location, self-similarity, and self-attribution. These scales, too, are presented on a disembodied Likert scale from 1 to 7. Additionally, we assessed the SoE several times during the VR experience using in-VR scales. We used the same scales for each assessment but adapted them to address either the embodied self-avatar, the embodied swap avatar, or the de-embodied self-avatar. We covered each of the dimensions of the VBO and VBO+ with one in-VR scale directly derived from these. All in-VR scales were presented on a scale from 0 (no agreement) to 10 (maximal agreement).

4.3.2 Interoceptive Awareness. To assess the trait of interoceptive awareness in advance, we used the Multidimensional Assessment of Interoceptive Awareness - Version 2 (MAIA) [48]. It comprises 37 items on the eight dimensions: noticing, non-distracting, not-worrying, attention regulation, emotional awareness, self-regulation,

[6] https://www.mcm.uni-wuerzburg.de/forschung/ethikkommission/

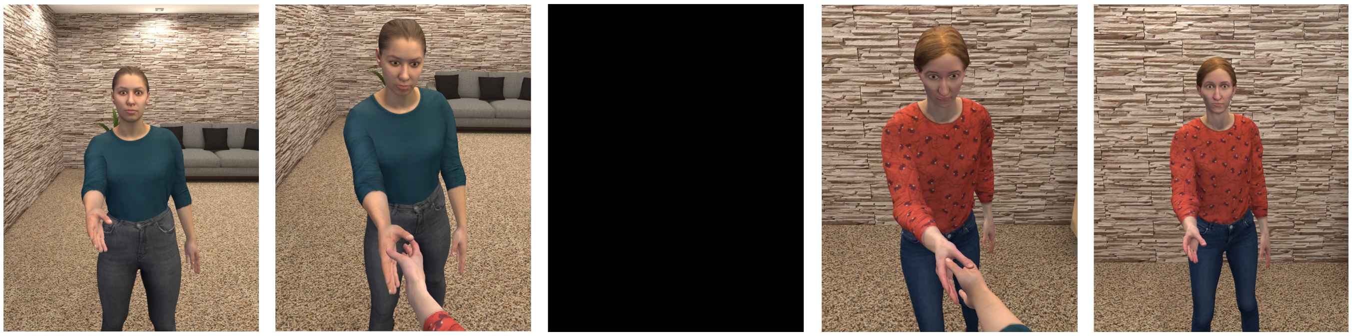

Figure 5: Exemplary participant's point of view before during the swap (from left to right).

body listening, and trusting. The scales are presented on a 6-point Likert scale from 0 to 5. We assessed the state of interoceptive awareness several times during the VR experience before and after the body swap, using in-VR scales as presented by Döllinger et al. [22]. These scales included noticing external signals (noticing external), noticing internal signals (noticing internal), body listening, attention regulation, and visual attention (preference of visual signals over other signals). Again, all in-VR scales were presented on a scale ranging from 1 to 10. Finally, we assessed the state of interoceptive awareness using the "body" dimensions of the State Mindfulness Scale (SMS) [70]. It comprises six items on a 5-point Likert scale ranging from 1 to 5. The SMS and the in-VR scales partially overlap. Thus, to ensure data economy, we assessed the SMS only post-VR.

4.3.3 Self-Compassion. We assessed the participant's traits in self-compassion using the Self-Compassion Scale - Short Form (SCS) pre-VR [60]. It comprises 12 items in six dimensions: self-kindness, self-judgment, common humanity, isolation, mindfulness, and over-identification. The items are presented on a 5-point Likert scale from 1 to 5. We assessed the state of self-compassion during the experience both pre- and post-VR using the State Self-Compassion Scale - Short Form (SSCS) [56]. It comprises six items. The items are presented on a 5-point Likert scale from 1 to 5.

4.3.4 User Experience. We assessed presence by using the One Item Presence Score (OIPS) [10]. The item was presented several times in VR on a scale of 1 to 10. We used semi-structured qualitative interviews to assess participants' qualitative experiences during the different tasks. The questions included the experience of the personalized avatar, the experience of the swap avatar, and the sensations during and after the body swap. They further included an evaluation of the meditation, the interactivity, and the motivation to repeat the experience.

4.4 Tasks

4.4.1 Embodiment Task. Each time embodying a new avatar, the participant performed simple body movements in front of the virtual mirror (see Figure 3), a common method to evoke a SoE [79]. The movement tasks were derived from Waltemate et al. [79]. They target different body parts for about 20 sec each. Following audio instructions, the participant waved at their mirror image, walked in place, and moved their hips while raising their arms. During these tasks, they were instructed to look at their mirror image and avatar from 1pp.

4.4.2 Self-Compassion Meditation. The VR experience was constructed to resemble a self-compassion meditation. The meditation procedure was derived from the guided meditations "Compassionate Friend" which introduces a compassionate friend and a perspective taking task and "Loving-Kindness Meditation" presented by Neff [55] which includes a row of positive affirmations directed at oneself. Accordingly, the swap partner was introduced as a compassionate friend in the virtual scenario and the self-compassion meditation included positive affirmations which were repeatedly presented to the participant. These included "may you be safe", "may you be at peace", "may you be healthy", and "May you go through life with ease and well-being".

4.5 Procedure

Our evaluation followed a standardized experimental procedure illustrated in Figure 6. Each experimental session was accompanied by a primary experimenter, who guided the participant through the session, and an assistant experimenter, who supported the avatar creation and embodied the swap avatar and personalized avatar during the VR experience. The assistant experimenter was selected to match the participant's gender but did not equal the female or male swap avatar. Participants were informed upfront that a person who was not the primary experimenter would be their swap partner but were not introduced to them as their swap partner until after the experiment. An experimental session included three phases: pre-VR, in-VR, and post-VR. Pre-VR, the participant read the study information, consented to the data collection, and created a pseudonymization code. In a second step, they were guided to the Embodiment Lab of the HCI Group at the University of Würzburg to perform the body scan for avatar creation. Afterward, the participant returned to the VR laboratory and answered MAIA, SCS, and SSCS questionnaires.

Figure 1 overviews the in-VR phase. In VR, all instructions were given via pre-recorded audio sequences, and some were additionally displayed on the virtual whiteboard (see Section 3.2). In the introduction phase, neither an avatar nor a mirror was visible. The participant performed a short vision test by reading text on the whiteboard to ensure the HMD was put on correctly. In the next step, the body tracking and embodiment system was calibrated. The

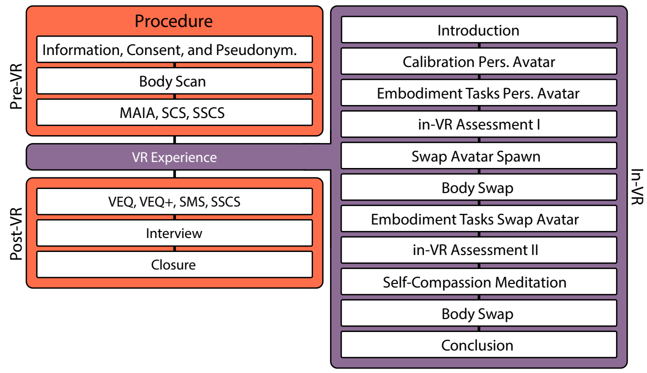

Figure 6: Overview of the experimental procedure.

personalized and the swap avatars were scaled to the participant's body height. The participant was instructed to perform a few idle movements and then stand still while facing the whiteboard.

To increase familiarity at the beginning of the in-VR phase, all participants started with embodying the personalized avatar. After the calibration, the participant's personalized embodied avatar and the virtual mirror appeared, and the whiteboard disappeared. To increase SoE, the participant performed the embodiment tasks (see Section 4.4.1). The whiteboard reappeared, and the participant answered the first in-VR scales about their interoceptive awareness and SoE toward their personalized avatar (in-VR assessment I). These in-VR scales were posed via audio instructions and the whiteboard, and the participant answered them verbally. Responses were noted by the experimenter. Following this, the footprints next to the circular marker appeared. The participant stepped on the footprints to their left. The swap partner was announced and introduced as a compassionate friend and appeared as the avatar (re-embody) or represented by two Knuckles (de-embody) in the position of the other footprints in front of the participant.

The participant initiated a first body swap (see Section 3.4). After the swap, the participant turned to the mirror and performed the embodiment tasks with their new appearance. They then turned to their personalized avatar and performed the self-compassion meditation (see Section 4.4.2). The whiteboard reappeared, and the participant was asked about their in-VR interoceptive awareness and in-VR SoE towards their personalized avatar and the swap avatar (in-VR assessment II). The participant then initiated a second body swap to return to their personalized avatar. The VR experience finished with a short scan of their bodily experience. Overall, the participant spent M = 23.40 min in VR. After putting down the VR equipment, the participant performed a second HCT and answered SSCS, SMS, UEQ, and Demographics questionnaires. Finally, the main experimenter performed the interview. The experimental session lasted M = 104.00 min.

5 RESULTS

5.1 Quantitative Results

5.1.1 Analysis. We calculated all analyses using R, including the packages *nlme*, *rstatix*, *report*. For plots, we used the package *ggplot2* and *ggpubr*. To analyze the effects of the swap (pre vs. post body swap) and the condition (de-embody vs. re-embody) on our in-VR measures (RQ 1.1, 1.2, 2.1, 2.2) and pre- and post-VR comparisons (RQ 3.1, 3.2), we fitted linear mixed models (estimated using REML and nlminb optimizer) to predict the respective dependent variable (formula: $dependent\ variable \sim swap\ (pre - post) \times condition$). The models included the participant id as random effect (formula: $1|id$). We report the t-values of individual comparisons within these mixed models. For analyses including only the condition (RQ 1.3, SoE toward the swap avatar), we calculated t-tests for independent groups. For the comparison between personalized and swap avatar (RQ 1.3), we calculated t-tests for paired groups. To analyze the relationship between SoE and self-related processes (RQ 1.4), we calculated simple linear regression models (formula:

Table 1: Descriptive results of pre-VR measures

		Overall	re-embody	de-embody
	Range	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Trait Interoceptive Awareness				
MAIA Attention regulation	[0–5]	2.91 (0.63)	2.74 (0.56)	3.07 (0.67)
MAIA Body listening	[0–5]	2.75 (0.79)	2.63 (0.62)	2.87 (0.95)
MAIA Emotional awareness	[0–5]	3.44 (0.90)	3.46 (1.01)	3.42 (0.83)
MAIA Self regulation	[0–5]	2.64 (0.86)	2.67 (0.99)	2.60 (0.77)
MAIA Non-distracting	[0–5]	2.84 (0.59)	3.10 (0.49)	2.58 (0.59)
MAIA Noticing	[0–5]	3.46 (0.66)	3.48 (0.58)	3.45 (0.76)
MAIA Not-worrying	[0–5]	2.70 (0.44)	2.94 (0.23)	2.46 (0.48)
MAIA Trusting	[0–5]	3.85 (0.74)	3.60 (0.89)	4.10 (0.47)
Self-Compassion				
SCS Self-judgement	[1–5]	2.58 (1.09)	3.00 (1.08)	2.15 (0.97)
SCS Self-kindness	[1–5]	3.25 (0.64)	3.15 (0.53)	3.35 (0.75)
SCS Common humanity	[1–5]	3.35 (0.99)	3.40 (0.97)	3.30 (1.06)
SCS Isolation	[1–5]	2.85 (1.05)	3.30 (1.06)	2.40 (0.88)
SCS Mindfulness	[1–5]	3.98 (0.75)	3.80 (0.71)	4.15 (0.78)
SCS Over-identification	[1–5]	3.28 (0.80)	3.60 (0.57)	2.95 (0.90)
SSCS	[1–5]	2.89 (0.38)	2.87 (0.23)	2.92 (0.50)

Table 2: Descriptive results of post-VR measures

		Overall	re-embody	de-embody
	Range	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
State Interoceptive Awareness				
SMS Body	[1–5]	3.29 (0.68)	3.40 (0.55)	3.18 (0.80)
Self Compassion				
SSCS	[1–5]	2.87 (0.41)	2.87 (0.27)	2.87 (0.53)
Sense of Embodiment (SoE)				
VEQ VBO	[1–7]	3.60 (1.53)	4.08 (1.61)	3.12 (1.37)
VEQ Agency	[1–7]	4.94 (1.34)	5.08 (1.21)	4.80 (1.52)
VEQ Change	[1–7]	3.34 (1.48)	3.02 (1.10)	3.65 (1.79)
VEQ+ Similarity	[1–7]	5.20 (0.98)	5.50 (1.03)	4.90 (0.88)
VEQ+ Location	[1–7]	3.76 (1.36)	4.05 (1.69)	3.48 (0.93)
VEQ+ Attribution	[1–7]	3.71 (1.67)	3.92 (2.04)	3.50 (1.26)

Table 3: Descriptive results of the in-VR measures

			Overall		de-embody		re-embody	
			pre swap	post swap	pre swap	post swap	pre swap	post swap
		Range	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Interoceptive Awareness	Noticing External	[1–10]	3.60 (2.26)	3.90 (2.34)	4.5 (2.68)	4.7 (2.58)	2.7 (1.34)	3.1 (1.85)
	Noticing Internal	[1–10]	5.90 (2.13)	6.15 (2.18)	6.3 (2.26)	6.5 (2.37)	5.5 (2.01)	5.8 (2.04)
	Body Listening	[1–10]	5.55 (2.46)	5.60 (2.21)	5.0 (2.71)	5.4 (2.55)	6.1 (2.18)	5.8 (1.93)
	Attention Regulation	[1–10]	6.65 (2.13)	5.95 (2.19)	6.2 (2.70)	6.1 (2.69)	7.1 (1.37)	5.8 (1.69)
	Visual Attention	[1–10]	6.85 (1.63)	5.90 (2.02)	7.2 (1.93)	5.7 (1.89)	6.5 (1.27)	6.1 (2.23)
SoE personalized avatar	in-VR VBO	[1–10]	4.50 (1.96)	4.75 (2.27)	5.0 (1.89)	4.9 (2.42)	4.0 (2.00)	4.6 (2.22)
	in-VR Agency	[1–10]	5.00 (2.29)	3.45 (2.11)	5.2 (2.20)	3.7 (2.16)	4.8 (2.49)	3.2 (2.15)
	in-VR Change	[1–10]	4.30 (1.95)	4.50 (2.26)	4.9 (2.13)	4.7 (2.11)	3.7 (1.64)	4.3 (2.50)
	in-VR Self-Similarity	[1–10]	6.55 (1.73)	6.20 (1.82)	7.1 (1.66)	5.9 (2.23)	6.0 (1.70)	6.5 (1.35)
	in-VR Self-Attribution	[1–10]	5.35 (2.11)	5.30 (2.11)	5.6 (2.17)	5.3 (2.21)	5.1 (2.13)	5.3 (2.11)
	in-VR Self-Location	[1–10]	3.45 (2.09)	2.80 (1.74)	4.0 (2.11)	3.2 (1.81)	2.9 (2.02)	2.4 (1.65)
SoE swap avatar	in-VR VBO	[1–10]	—	2.80 (2.07)	—	2.6 (2.41)	—	3.0 (1.76)
	in-VR Agency	[1–10]	—	3.45 (2.44)	—	1.7 (1.06)	—	5.2 (2.15)
	in-VR Change	[1–10]	—	4.45 (3.36)	—	3.0 (2.98)	—	5.9 (3.21)
	in-VR Self-Similarity	[1–10]	—	2.80 (2.09)	—	2.7 (2.41)	—	2.9 (1.85)
	in-VR Self-Attribution	[1–10]	—	2.80 (2.12)	—	2.5 (2.27)	—	3.1 (2.02)
	in-VR Self-Location	[1–10]	—	2.65 (1.84)	—	2.1 (1.37)	—	3.2 (2.15)
Sense of Presence		[1–10]	5.5 (1.79)	5.45 (2.28)	5.9 (1.60)	5.2 (2.62)	5.1 (1.97)	5.7 (2.00)

$self\text{-}reported\ process \sim SoE$), using the post-VR measures SMS Body, SSCS, VEQ, and VEQ+. All models were tested against an alpha of .05. The descriptive results of the pre-VR assessments on interoceptive awareness and self-compassion can be found in Table 1. The descriptive results of the post-VR assessments on SoE, interoceptive awareness and self-compassion can be found in Table 2. The descriptive results of the in-VR assessments on SoE and interoceptive awareness can be found in Table 3.

5.1.2 *Effects on Avatar Perception.*

SoE toward the Personalized Avatar. The swap negatively affected (RQ 1.1) on in-VR Agency, $\beta = -1.50$, $95\%\ CI[-2.94, -0.06]$, $t(18) = -2.18$, $p = .042$, and on in-VR Self-Similarity, $\beta = -1.20$, $95\%\ CI[-2.14, -0.26]$, $t(18) = -2.68$, $p = .015$ (see Figure 7). We did not find a significant effect on in-VR VBO, $\beta = -0.10$, $95\%\ CI[-1.60, 1.40]$, $t(18) = -0.14$, $p = 0.890$, Change, $\beta = -0.20$, $95\%\ CI[-1.97, 1.57]$, $t(18) = -0.24$, $p = 0.815$, Self-Attribution, $\beta = -0.30$, $95\%\ CI[-1.18, 0.58]$, $t(18) = -0.71$, $p = 0.484$, or Self-Location, $\beta = -0.80$, $95\%\ CI[-1.77, 0.17]$, $t(18) = -1.74$, $p = .099$.

Regarding RQ1.2, we did not find an effect of our condition on our in-VR SoE scales. We found neither an effect on in-VR VBO, $\beta = -1.00$, $95\%\ CI[-3.01, 1.01]$, $t(18) = -1.04$, $p = .311$, Agency, $\beta = -0.40$, $95\%\ CI[-2.52, 1.72]$, $t(18) = -0.40$, $p = .696$, Change, $\beta = -1.20$, $95\%\ CI[-3.19, 0.79]$, $t(18) = -1.27$, $p = .221$, Self-Location, $\beta = -1.10$, $95\%\ CI[-2.89, 0.69]$, $t(18) = -1.29$, $p = .213$, Self-Similarity, $beta = -1.10$, $95\%\ CI[-2.76, 0.56]$, $t(18) = -1.39$, $p = 0.181$, or Self-Attribution, $\beta = -0.50$, $95\%\ CI[-2.53, 1.53]$, $t(18) = -0.52$, $p = .611$.

SoE toward the Swap Avatar. Regarding the SoE toward the swap avatar, our in-VR measures (RQ 1.3) revealed a significant effect of the condition on in-VR Agency, $\beta = 3.50$, $95\%CI[1.91, 5.09]$, $t(18) = 4.62$, $p < .001$. We did not find a significant effect of condition on in-VR VBO, $\beta = 0.40$, $95\%CI[-1.59, 2.39]$, $t(18) = 0.42$, $p = 0.677$, in-VR Change, $\beta = 2.90$, $95\%CI[-0.01, 5.81]$, $t(18) = 2.09$, $p = 0.051$, in-VR Self-Similarity, $\beta = 0.20$, $95\%CI[-1.82, 2.22]$, $t(18) = 0.21$, $p = 0.837$, in-VR Self-Location, $\beta = 1.10$, $95\%CI[-0.59, 2.79]$, $t(18) = 1.36$, $p = 0.189$, or in-VR Self-Attribution, $\beta = 0.60$, $95\%CI[-1.42, 2.62]$, $t(18) = 0.62$, $p = 0.541$. In addition, participants reported significantly higher in-VR VBO, $t(19) = -2.78$, $p = .012$, $95\%\ CI[-3.42, -0.482]$, Self-Similarity, $t(19) = -5.63$, $p < .001$, $95\%\ CI[-4.66, -2.14]$, and Self-Attribution, $t(19) = -4.39$, $p < .001$, $95\%\ CI[-3.69, -1.31]$, toward their personalized avatar from 3pp than toward the embodied swap-avatar (see Figure 8). Here, we did not find a significant effect regarding Agency, $t(19) < .01$, $p > .999$, $95\%\ CI[-1.38, 1.38]$, Change, $t(19) = -0.06$, $p = .953$, $95\%\ CI[-1.80, 1.70]$, or Self-Location, $t(19) = -0.27$, $p = .788$, $95\%\ CI[-1.30, 1.00]$. Finally, we found higher Agency ratings for the visible swap avatar than the personalized avatar in the re-embody condition, $t(9) = 3.46$, $p = .007$, $95\%\ CI[0.69, 3.31]$.

5.1.3 *Relationship between SoE and Self-Related Processes.*

Regarding the relationship between SoE and interoceptive awareness (RQ 1.4), our regression models revealed a positive relationship between VEQ VBO toward the personalized avatar and SMS Body, $R^2_{adj} = 0.24$, $F(1, 18) = 7.08$, $p = .016$, between VEQ Agency and SMS Body, $R^2_{adj} = 0.56$, $F(1, 18) = 25.63$, $p < .001$, and between VEQ Change and SMS Body, $R^2_{adj} = 0.32$, $F(1, 18) = 9.89$, $p = .006$ (see Figure 9). We did not find a significant relationship between VEQ+ Similarity and SMS Body, $R^2_{adj} < 0.01$, $F(1, 18) = 1.04$, $p = .320$, between VEQ+ Location and SMS Body, $R^2_{adj} = 0.11$, $F(1, 18) = 3.30$, $p = .086$, or VEQ Attribution and SMS Body, $R^2_{adj} < 0.01$, $F(1, 18) = 1.07$, $p = .315$.

Regarding self-compassion and SoE toward the personalized avatar, we did not find any significant relationship, neither for

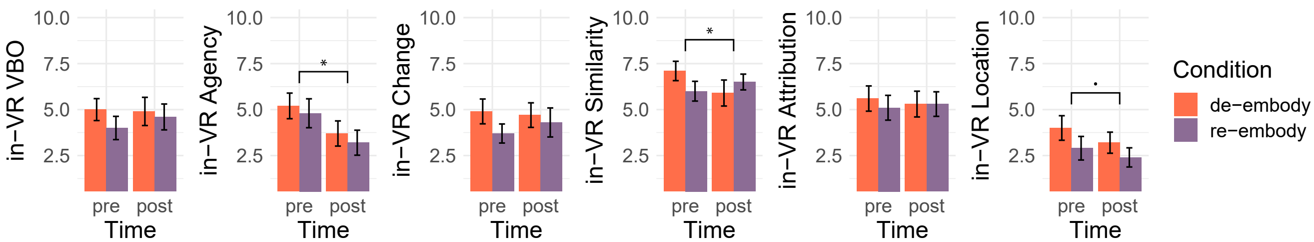

Figure 7: Results of the in-VR measures for SoE toward the personalized avatar ('·' $p < .1$; '*' $p < .05$).

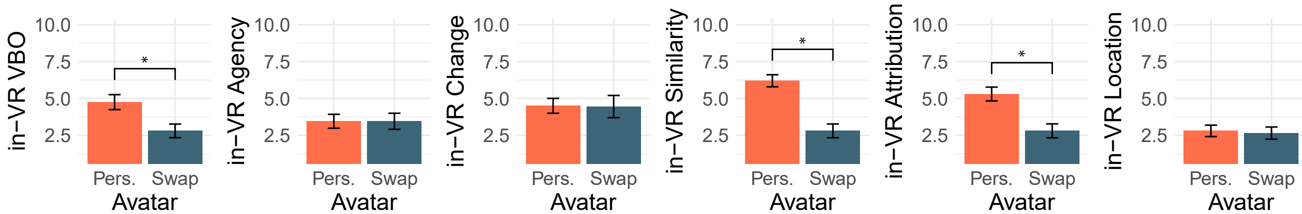

Figure 8: Comparison between the 3pp personalized avatar and the 1pp swap avatar after the swap (both conditions; '*' $p < .05$; Pers. = personalized avatar, Swap = swap avatar).

VEQ VBO, $R^2_{adj} = 0.07$, $F(1, 18) = 2.52$, $p = .130$, VEQ Agency, $R^2_{adj} = 0.10$, $F(1, 18) = 3.15$, $p = 0.092$, VEQ Change, $R^2_{adj} = 0.06$, $F(1, 18) = 2.11$, $p = .164$, VEQ+ Similarity, $R^2_{adj} = -0.04$, $F(1, 18) = 0.22$, $p = .643$, VEQ+ Location, $R^2_{adj} = -0.02$, $F(1, 18) = 0.63$, $p = .439$, nor VEQ+ Attribution, $R^2_{adj} = 0.09$, $F(1, 18) = 2.98$, $p = .101$.

5.1.4 *Effects on Self-Related Processes.*

Interoceptive Awareness. Regarding RQ 2.1 and RQ 2.2 regarding the effects of the swap and our conditions on interoceptive awareness, we found the following. In VR, we found a significant positive effect of the swap on Body Listening, $\beta = 1.50$, $95\% CI[0.11, 2.89]$, $t(18) = 2.27$, $p = .036$, and a negative effect on Visual Attention, $\beta = -1.50$, $95\% CI[-2.78, -0.22]$, $t(18) = -2.46$, $p = .024$ (see Figure 10). Participants reported increased body listening and decreased focus on visual signals after the swap. We did not find a swap effect on Noticing External, $\beta = -0.30$, $95\%\ CI[-1.18, 0.58]$, $t(18) = -0.71$, $p = 0.484$, Noticing Internal, $\beta = 0.20$, $95\%\ CI[-0.79, 1.19]$, $t(18) = 0.43$, $p = 0.675$, and Attention Regulation, $\beta = -0.10$, $95\%\ CI[-1.15, 0.95]$, $t(18) = -0.20$, $p = 0.844$.

We did not find an effect of our conditions on Noticing External, $\beta = -1.80$, $95\%\ CI[-3.85, 0.25]$, $t(18) = -1.84$, $p = .082$, Noticing Internal, $\beta = -0.80$, $95\%\ CI[-2.85, 1.25]$, $t(18) = -0.82$, $p = .422$, Body Listening, $\beta = 1.10$, $95\%\ CI[-1.10, 3.30]$, $t(18) = 1.05$, $p = .307$, Attention Regulation, $\beta = 0.90$, $95\%\ CI[-1.16, 2.96]$, $t(18) = 0.92$, $p = .371$, or Visual Attention, $\beta = -0.70$, $95\%\ CI[-2.45, 1.05]$, $t(18) = -0.84$, $p = .412$. Post-VR, we did not find a significant effect of the condition on SMS Body, $t(15.94) = 0.70$, $p = .492$.

Self-Compassion. Regarding self-compassion (RQ 3.1 and 3.2), we did not find an effect of the swap, $\beta = -2.45e-15$, $95\%\ CI\ [-0.12, 0.12]$, $t(18) = -4.19e-14$, $p > .999$, nor of condition, $\beta = 0.05$, $95\%\ CI[-0.33, 0.43]$, $t(18) = 0.28$, $p = .786$, on the SSCS.

5.2 Qualitative Results and User Experience

5.2.1 *Analysis.* To analyze the qualitative data, we applied a summarizing content analysis [47] and rated the valence of each statement (positive, negative, or neutral). Two team members performed the analysis separately and then merged category by category. In the following, we present the results of this analysis regarding the user experience of the two avatars, the body swap and the meditation. Finally, we added some suggestions from the participants on design ideas for interactive tasks.

5.2.2 *User Experience of the Avatars.*

Experience of the Personalized Avatar. Before the swap, most participants reported positive affect toward their personalized avatar (11× positive, 4× negative). However, especially in the de-embody condition, an adverse change in mood occurred after the swap (10×). Participants reasoned the avatar seemed eerier from the new perspective or that it was eerie not to be able to control it: "Yes, it [the perception of my avatar] had changed. It felt more uncomfortable, more eerie than before. Not having control over the avatar is creepy." [participant 14]. Others perceived no change in mood (5×) or even perceived the personalized avatar more positively after the swap (4×), stating that it was "quite cool to look at oneself from the outside" [participant 12]. Twelve participants positively highlighted the appearance of the avatar, focusing on having a lower body (3×), a high similarity and realism (7×), and the realistic appearance of the avatar's clothes (2×). Further, two participants highlighted the

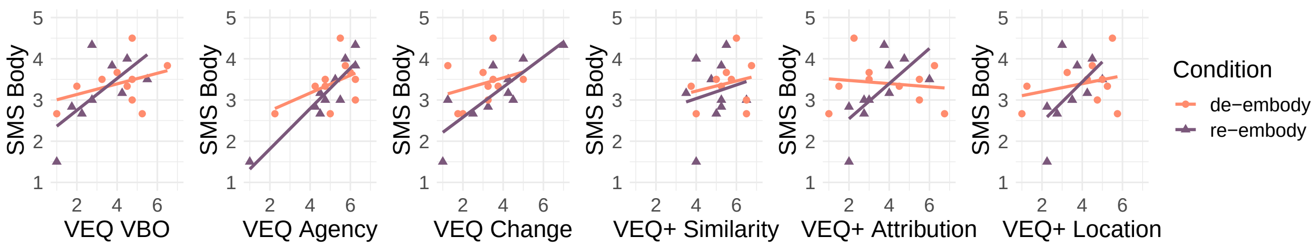

Figure 9: Relationship between SoE and interoceptive awareness ('∗' $p < .05$).

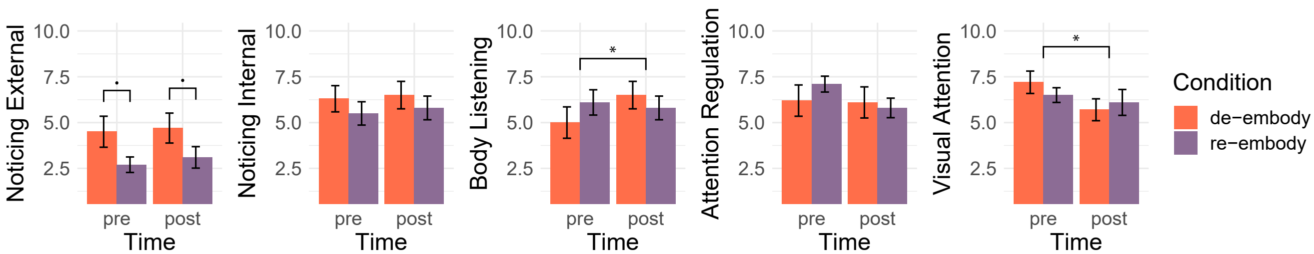

Figure 10: Results of the in-VR measures for interoceptive awareness ('·' $p < .1$; '∗' $p < .05$).

hand tracking, and two stated that they enjoyed seeing themselves from a new perspective. However, participants also gave a critical review of the avatar's realism. Four disliked the non-personalized hands of the avatars. Eleven stated inaccuracies in the appearance of the avatar's face, including their eyes (4×) or eye color (3×), their overall facial structures (2×), or their mouth (2×). One participant disliked the appearance of the avatar's pants. Five participants did not associate with their avatar's body posture (2×).

Experience of the Swap Avatar. Concerning the swap avatar, half of the participants initially expressed neutral feelings (10×). In line with our expectations, the two conditions differed here. In re-embody, some participants expressed positive feelings (3×), e.g., stating: "It was familiar as if a brother or good friend was standing next to me" [participant 17]. In de-embody, some participants were unpleasantly touched (3×) or confused (4×) because the invisibility of the swap partner did not correspond to their expectations: "It was weird because it wasn't a person but nothing" [participant 2]. After the swap, this surprise effect dissipated. Many participants still felt neutral toward the swap avatar (9×, 4 of them in re-embody, 5 in de-embody). However, in both groups, negative feelings towards the swap avatar arose (8×, 4 in each condition). Participants reasoned that it felt "strange" and that there was a difference in SoE compared to the personalized avatar. Only a few participants interpreted the swap avatar as positive after the swap (3×). Participant 19 stated: "I felt good, more comfortable than in my own avatar, you don't have to compare to reality. I am in VR, I am free".

5.2.3 User Experience of the Body Swap.

Experience of the General Perceptive Shift. The body swap interaction was rated mostly neutrally (11×, 5 in re-embody, 6 in de-embody) or positively (7×, 4 in re-embody, 3 in de-embody). Only two participants reported a negative experience. Participant 20 reasoned: "I didn't feel comfortable in my own avatar and even less so in someone else's, you couldn't identify with it at all".

Ten participants reported (6 in re-embody, 3 in de-embody) that the swap did not trigger any feeling of awe, reasoning that they would have expected more of it. However, eight participants rated the swap astounding, exciting, or "cool". Participant 3 explained: "[I felt like] 'Wow' because I've never seen myself from the outside before". Participant 9 stated: "It's amazing that this is possible. I didn't think my avatar would be so detailed". Ten participants expected the experience to change with repeated exposure regarding future use. Participant 18 stated: "You would probably become better at self-reflection and positive thinking".

Specifications of the Current Technology. The blackening of the display during the swap mainly was perceived as positive (10×) or neutral (3×) and interpreted as a relaxing pause between tasks. However, some participants found it disturbing (3×) or too long (4×). The physical handshake to trigger the body swap was reviewed critically. One participant liked the physical handshake: "I felt the hand and had a point of contact, so it was more realistic and better than if the body swap had happened suddenly" [participant 3]. However, seven participants reported ambivalent feelings, either disliking the indirectness of the controllers (3×) or the mixture of virtual and physical signals (4×), stating, e.g.: "It was interesting to touch another real person in VR. But you realized that there was a discrepancy between VR and reality" [participant 18].

5.2.4 User Experience of the Meditation Task. Some participants reported engaging well with the audio-guided self-compassion meditation (7×, 5 in re-embody, 2 in de-embody). They liked its content (6×), especially the pre-formulated sentences and positive affirmations (5×) and the adaptation of sentences over time (1×). They further liked the execution of the meditation (5×), the concept of looking at their avatar during the meditation (3×), the voice of the instructor (1×), and that there was little distraction in the virtual world (1×). Three participants liked the effect of the meditation, as they experienced it as relaxing and calming.

However, others could not concentrate on the meditation (11×, 3 in re-embody, 8 in de-embody). Participant 2 stated: "It was strange to address [the affirmations] to me on the one hand and to the avatar on the other. A normal meditation where I still am myself would have been easier". Some participants had issues with the execution of the meditation (5×). Some felt insecure during the meditation as they did not know whether they should enunciate the affirmations (1×) or felt the urge to close their eyes to focus on the meditation and were unsure whether it was allowed (1×). Others disliked the frequency of repeating the affirmations (3×), rating them as too often, too fast, or too intrusive. One participant found the virtual environment not suitable for meditation. Regarding the meditation content, two participants found the affirmations weirdly worded.

5.2.5 Ideas and Suggestions for Future Developments.

Virtual and Human Swap Partners. Participants expressed diverse preferences regarding the design of the swap avatar, grouped into visibility, anthropomorphism, self-similarity, and familiarity. Four participants addressed the visibility of the swap avatar. While three preferred an invisible partner, one preferred to swap with a visible avatar. Seven participants discussed anthropomorphism. Two stated that the avatars should be designed even more realistically: "It would be better if the virtual aspect wasn't so present and the avatars were more human. Overall, just more realistic would be better" [participant 18]. However, four participants suggested deviations from realism, using animals (1×), fantasy or mythical creatures (3×), or more inconspicuously, with shadow figures (1×) as swap avatars. Six participants stressed the importance of similarity between the swap avatar and the user, stating, e.g., it should be "Similar to me, in appearance and character, so I can best identify and feel comfortable" [participant 8]. Specifically, some were concerned about gender (2×) or age (1×). In contrast, one participant suggested using a swap avatar distinct to the user in gender, appearance, weight, and height. Finally, commenting on familiarity, some participants preferred swapping with a familiar avatar (3×) or a famous person (1×). Others preferred an unfamiliar swap avatar. Finally, four participants stated that the appearance of the swap partner did not matter to them.

Participants answered diversely when asked whether they would allow another person to control their personalized avatar in the future. A majority stated no restrictions (14×). Others emphasized the importance of familiarity with the other person (5×), varying between "only someone I trust" (2×), "only people I know and like" (1×), and "only friends or family" (2×). Participant 18 stated they would rather not have anyone embody their personalized avatar, at least not if they were not there themselves.

Interactive Tasks. Participants suggested various alternative tasks to perform with their de-embodied avatars. A large part of the suggestions focused on joint physical activities, with the avatar not necessarily being the main focus of the activity (16×). These included exploring novel environments (3×), sports or games activities (4×), more active movements (5×), or going out to eat together (2×). Other suggestions focused on the avatar itself. For example, participants suggested talking to the avatar (4×) or having the opportunity to walk around it and look at it from all sides (5×). Furthermore, participants emphasized using activities only possible in VR (1×). One participant noted that engaging in an interactive exercise would be easier if they had a visible swap avatar. Finally, four participants stated they did not want to interact with their personalized avatar or had no idea what to do with it.

6 DISCUSSION

We presented a multi-user embodiment system enabling users to embody personalized and generic virtual avatars and exchange perspectives. Our evaluation results bring new insights into the SoE toward personalized avatars (RQ 1.1-1.3). Leaving the 1pp of a personalized avatar, participants reported reduced feelings of agency or self-location but not of the more appearance-based dimensions of SoE or VBO. These variables were still rated higher toward the personalized 3pp avatar than a generic 1pp avatar. Moreover, they were positively associated with interoceptive awareness (RQ 1.4). We further showed that while our intervention did not notably impact self-compassion, the virtual body swap not necessarily negatively affected self-related processes (RQ2.1-3.2). In contrast, we found a slight pre-post increase in body listening and a shift from virtual to bodily experiences (swap effect).

6.1 Leaving First-Person Perspective

In our experiment, leaving the 1pp of one's personalized avatar reduced the SoE over it. However, when taking a closer look at the dimensions of SoE, it becomes apparent that we must differentiate between the dimensions of SoE. Participants reported a reduction in dimensions related to the position and behavior of the avatar, with a significant effect on agency and a tendency on self-location. However, they did not report a reduction in the identification with the avatar, including self-attribution, change, or VBO. This result indicates a reduction of bottom-up SoE [42]. The continued strong top-down self-attribution and VBO highlight the necessity to distinguish between recognizing the shift in position and control and an actual higher-cognitive dis-embodiment effect.

Increasing the mental distance between an individual and their personalized avatar while maintaining self-attribution and VBO holds promise for various applications. Besides perspective-taking exercises, numerous psychotherapeutic approaches aim at creating self-distancing to support self-reflection [43]. Spatially distancing oneself from a virtual self could facilitate this mental disassociation. Further, embodying different personas during this self-distancing might offer benefits in mentally gaining new perspectives. For example, regarding individuals with eating or body image disorders, past research has shown that embodying and seeing different versions of one's personalized avatar can impact participants' body image and body weight perception [26, 72, 85]. Distancing oneself from one's avatar and embodying different perspectives on one's body could further enhance such interventions.

Interestingly, participants reported reduced self-similarity after the swap as they could see the personalized avatar's face from a closer distance. Regarding the qualitative answers, this closer perspective led to an increased feeling of uncanniness, as minor discrepancies between avatar and participant became more apparent. In addition to continuously improving the quality of personalized avatars, one solution would be to rely on more abstract avatars and thus reduce the risk of an uncanny valley effect [64]. However, such abstraction could limit applicability, as less detailed personalized avatars might reduce self-attribution [23, 62]. On a more superordinate level, it could be useful to identify the reasons behind discomfort and disassociation with one's personalized avatar. Some participants reported discomfort with the reduction of control over it after the swap. Revising the introduction and initiation of the body swap could increase comfort and strengthen the communication between the instructor and the participant.

6.2 After the Swap: Dis- or Multi-Embodiment?

Matching the findings regarding the personalized avatar, participants reported a lower SoE toward the swap avatar in some dimensions, while in others, they prioritized the swap avatar. This distinction differentiates between bottom-up SoE dimensions of avatar position and behavior and top-down dimensions of identification with the avatar and its appearance. Participants reported a higher sense of agency toward the swap avatar, at least in the re-embody condition. However, they did not prioritize the sense of self-location between the avatars. Regarding the identification with and appearance of the avatar, participants preferred their personalized avatar, reporting higher self-similarity, self-attribution, and VBO. Consequently, they distinguished clearly between the more top-down oriented identification with an avatar, which remains with the personalized avatar, and the assessment of their bottom-up perceptible positioning and agency in the virtual environment.

One could argue that participants felt multi- or dual-embodiment [36] effect regarding the bottom-up dimensions of SoE. While still identifying with their personalized representation, participants did not feel located stronger in one of the avatars than in the other. However, this also raises the question of whether a multi-embodiment effect can be reduced to its bottom-up processes. Even after the swap, participants identified with and felt VBO toward the personalized avatar, potentially given its appearance similarity. Previous studies used avatars matching each other's appearance [36], leading to a sense of dual embodiment through bottom-up stimulation. In other work, different-looking avatars affected SoE toward the swap avatar [66]. However, whether participants still felt associated with their primary avatar was not investigated. It remains questionable whether typical embodiment effects [82] are also effective in the presence of a non-embodied personalized avatar.

6.3 After the Swap: Self-Related Processes

We observed a positive correlation between post-VR measures of interoceptive awareness and SoE toward the personalized avatar, particularly in bottom-up oriented agency and the more top-down oriented VBO, change, and self-location. This outcome aligns with previous findings indicating a positive relationship between SoE and interoceptive awareness [15, 22, 23]. Our pre-post results on interoceptive awareness (swap effect) contradict the assumption that embodying avatars might reduce interoceptive awareness due to distraction or increased workload [23, 49]. In our study, subjects engaged simultaneously with two avatars, each evoking varying degrees of SoE. According to mental load theory, this dual load should reduce bodily sensations' processing capacity. However, our findings did not show such a reduction. Participants reported no significant swap effect in most interoceptive awareness ratings and a slight increase in body listening. Notably, they shifted focus from visual to bodily signals after the swap. Additionally, some participants enjoyed the meditation and anticipated positive effects over time. This result suggests that habituation or engaging playfully with the avatar could compensate for a potential initial decline of body awareness [22].

It is crucial to balance the technical capabilities, including real-time body swapping, with the original goals of increasing self-compassion. Unfortunately, we did not find a positive effect of our exercises on self-compassion, nor a difference between conditions. In general, the state self-compassion ratings in our sample were relatively high, indicating the possibility of a ceiling effect. Testing with a more diverse sample could help gain insights into the effects of virtual body swapping on self-compassion. On the other hand, participants reported having trouble focusing on the meditation. The novel experience of embodying a personalized avatar and the even more novel experience of body swapping might have suppressed the potential outcomes of our intervention. Finally, considering the main criticism of the self-compassion exercise, the rigidity and potentially unclear instructions of the meditation exercise stick out. While the meditation task was derived from an established self-compassion exercise [55], the VR implementation led to some confusion. Learning from our results, future interfaces should work on clarifying the direction of affirmations and individualizing their phrasing and pacing or creating more interactivity during the exposure.

6.4 Personalized Avatars as Social Actors

Regarding the perception of the personalized avatar, an exciting new question arises. Our research focused on perceiving the avatar as part of the self and the SoE. Self-identification persisted even when the avatar was left and participants embodied a second, uninvolved avatar. We take this as a positive indicator for future virtual out-of-body experiences [17]. Participants suggested various activities for their avatars, prompting a question whether the personalized avatar could be seen as a social partner. Given the external perspective on and external control of the avatar, some alienation between the user and avatar might occur, potentially causing a shift in self-location and agency. Future work will show whether this alienation leads to an experience of the avatar as a social presence [57].

Further, our results form a basis for future work regarding the choice of swap avatar. In earlier studies, the swap avatar representing an authority figure by its role as a therapist increased the positive effects of a self-counseling task compared to a personalized avatar [58, 66]. Compared to that, we created swap avatars matching the peer group of most of our participants, framed them as compassionate friends without suggesting authority, and compared them to an invisible swap partner. Except for agency, we found no differences between these conditions regarding SoE. Additionally, we received mixed feedback regarding the experience of not having a 1pp avatar after the swap. Participants expressed only a few remarks about the swap avatars besides not feeling as embodied in them as in the personalized avatar. This may have contributed to the lack of an effect on self-compassion. The effects of the previous studies are likely due to an underlying Proteus effect. To create a Proteus effect, an avatar must elicit a stereotypical association, such as Freud as a good counselor [58] or Einstein as a mathematical genius [6]. To focus on the personalized avatar, we used peers as swap avatars that potentially did not trigger strong stereotypes. However, given the potentials of the Proteus effect, creating swap avatars with a stronger association with intervention goals, such as compassion or empathy, might be a key factor in designing a virtual self-compassion intervention.

6.5 Future Work: Designing Virtual Perspective Shifts in Mind-Body Interventions

While our results do not answer all questions on the perception of virtual avatars and self-related processes in virtual body-swapping, they offer some insights for future research. Considering the design space of a virtual perspective change out of one's personalized avatar, various settings can be adjusted. In the following, we discuss requirements, challenges, and open questions regarding the appearance and behavior of different design elements across different moments of the experience.

6.5.1 The Personalized Avatar. In our scenario, photorealistic personalized representations of participants served as avatars. Past work highlights a positive impact of realism and personalization on SoE [52], yet it remains unclear whether this poses a risk for self-related processes [23]. However, to stimulate self-related processes, we see personalization as a possible opportunity. Participants highly identified with their avatar even when placed outside of it. Beyond appearance, the avatar's body language post-body swap may be pivotal. Creating similarities or deviations between participant behavior and avatar movements could be an exciting tool to impact self-identification or self-related processing, as body language affects the perception of compassion [5]. Controlling for possible uncanny valley effects [40], we see great potential for future investigations into how changes in the appearance or behavior of the avatar affect self-perception.

6.5.2 The Design of the Swap Avatar. Past research has shown great application potential, especially concerning the swap avatar's appearance. By swapping with a mentor [58] or changing into a childlike avatar [27], participants experienced support in their self-reflection. The suggestions of our participants show that the preferences regarding the swap avatar's appearance can be very individual. As mentioned, we opted for peers as swap avatars, not aiming at a Proteus effect but a focus on the personalized avatar. Besides that, the choice of our visible swap avatars and our human swap partners may have impacted our results. First, we intentionally limited our selection of swap avatars to two that were gender-matched to the participants but not further individualized. Second, we ensured the participants did not know the swap avatars before the experience. Studies of avatar individualization have shown their relevance in eliciting VBO [81] while critically evaluating the importance of considering user preferences [30], and effects on self-related processes such as body awareness [23]. Expanding these findings considering swap avatars and familiarity could be the next step in furthering the knowledge about the effects of avatar appearance on user experience.

6.5.3 Behind the Scenes: The Swap Partner. A body swap scenario involves a user, their current avatar, their swap avatar, and the unit controlling the swap avatar. Our participants differed in their preferences regarding who could embody and control their personalized avatars. Some mentioned allowing only a trusted person or no one. This raises the question of who might be a suitable partner behind the swap avatar. In our scenario, the swap partner was an assistant experimenter sharing the physical space with the participant. This created a co-embodiment situation in which subjects continued to feel associated with their personalized avatar while another person could view and control it from 1pp. Alternatives are imaginable. One option involves a swap agent with computer-controlled animations instead of a human-embodied swap avatar. Using a swap agent could offer increased situational control, which can be particularly advantageous in phobia or anxiety [67]. Computer-animating the personalized avatar facilitates adapting its body language to the user. A second option could involve not animating the avatar currently not embodied by the user. Besides further increasing control, this option would allow for a focus on the body without the effect of possibly unfamiliar body language.

Regarding a human swap partner, their relationship with the participant and their correspondence with the swap avatar raise the potential for future work. Some participants expressed the preference for swapping with someone familiar. The next step in intervention development could be to investigate how swapping with a familiar partner might affect the perception of the body swap. Additionally, it might be relevant to elaborate on whether familiarity with the swap avatar or the person controlling it is dominant in affecting the body swap experience. Since our participants expressed very individual preferences and fears toward the swap partner, future work should investigate how the swap partner affects the person's social and self-related processes.

6.5.4 The Design Space of the Swap. We used a handshake gesture to initiate the body swap, framing it as a swap even when the partner was invisible. While a handshake might be appropriate in some cultures, others may prefer alternative consensual gestures. Additionally, different framings are possible depending on the appearance and the use of a human or computer-controlled swap avatar. For example, stepping out of 1pp might be more beneficial in some situations. It would allow complete control over the speed of leaving 1pp and the perspective taken on. Further, it would prevent giving up control to another person embodying one's avatar. Again, especially for individuals dealing with anxiety or body image issues, increasing control over the situation could be beneficial [67]. In other situations, a targeted swap with another person could be preferable. As indicated by the participant's comments on potential swap partners, a body swap, compared to a simple perspective change, might raise the interaction to a new level. Swapping bodies allows participants to work with their bodies while creating real social interaction. Therefore, adapting to the respective necessities of different therapeutic or non-therapeutic situations is crucial.

Similarly, the swap initiation can be presented variously. Our participants' feedback mainly focused on the duration of the blackening between the swap and the indirect touch via the hand controllers. Future work could elaborate more deeply on which interactions benefit different use cases.

6.5.5 Interactive Self-Compassion. Finally, another design element of the swap scenario is the post-swap exercises. While some subjects welcomed the quiet meditation in our design, others found it challenging to engage with, and we did not find a positive impact on self-compassion. Participants suggested post-swap exercises, predominantly involving shared physical activities or social interaction with the personalized avatar, aligning to prior work [58]. Further, participants' opinions varied regarding the verbal task instructions. Future work could investigate how different exercises and interactions benefit self-related processes in mind-body interventions and how these can be implemented.

6.5.6 Risk Factors. In this initial evaluation of our prototype with healthy participants, some concerns emerged that merit attention in future work. Some participants expressed concern about who might experience their personalized avatar from 1pp. These concerns spotlight an issue regarding intimacy in virtual spaces. It is crucial to investigate whether allowing someone else to control an individual's personalized avatar is perceived as intimate. A virtual body swap might not inherently invade intimate space [38], given the absence of physical proximity from 1pp. Nevertheless, the experience of a third-party embodiment could affect the perceived intimacy or cause a loss of control over one's bodily depiction. A second concern expressed by participants was discomfort with embodying another character while their personalized avatar coexisted in the same virtual space. Again, future work must probe whether this scenario triggers adverse emotions and how to counteract them. Thirdly, some participants experienced an uncanny valley effect after the body swap, perceiving a reduced self-similarity between themselves and the avatar. This finding could be due to the novel perspective but also to the design of the avatars. Further investigation is necessary to avoid this effect in future implementations.

6.5.7 Individualization. In summary, diverse and sometimes conflicting preferences and concerns were evident among participants regarding various design elements, be it the personalized avatar, the swap avatar, the swap partner, or the interaction. While self-related processes can be considered overarching for mind-body interventions [12], addressing individuals' distinct needs is crucial. Hence, future work should aim to identify and incorporate respective target groups' specific needs and vulnerabilities into the design of virtual body swaps or other mind-body-oriented virtual self-encounters.

6.6 Limitations

In addition to the potential social presence effects and lack of control regarding the similarity between our participants and the swap avatars mentioned above, we want to point out a few limitations.

In this study, all participants started by embodying the personalized avatar. This sequence could have impacted our findings, considering that the order in which different avatar types are embodied can affect how users perceive them [21]. We opted for this design to make it easy for participants to familiarize themselves with the virtual environment. A reasonable alternative for future studies could be to use a balanced design with participants either embodying their personalized or the respective swap avatar first. That way, the "compassionate friend" would be represented by either the personalized or the swap avatar. As prior work has shown, the identity of an avatar can determine the efficacy of avatar-mediated interventions [58]. Thus, providing insights into whether this is the case for self-compassion settings could be the next step in illustrating the effect of avatar identity on therapy-relevant outcomes.

In addition, while we explored various dimensions of SoE, we did not include a behavioral measure of SoE. Typically, methods like a virtual threat are used to measure VBO objectively [37]. While integrating a threat measure would have raised additional ethical concerns in our study, there is another reason for its exclusion. Adding a threat could affect how users empathize with their avatar, potentially biasing the outcomes of a self-compassion task. Nonetheless, it would be a good opportunity for future work to close this gap and determine how participants react visually to their de-embodied, personalized avatars being threatened.

Finally, our results are limited concerning our sample. We tested with a relatively small sample size, allowing extensive interviews after the experience but preventing the calculation of interaction or moderating effects between dependent variables. Particularly in the interaction between SoE and interoceptive awareness, investigating with a larger sample would have been interesting to determine whether the SoE plays an additional role in interoception compared to the swap avatar. Additionally, our sample was relatively homogeneous, consisting of young, healthy students with limited VR experience. All participants confirmed being comfortable with another person controlling their personalized avatar. Our data might be limited here, as we do not know how people with a stronger sense of intimacy or a lower self-compassion would respond to our system. However, our study marks the initial evaluation of our system. Consequently, concerning the potential risks associated with body-swapping, our findings represent a crucial initial stride toward future research involving more vulnerable demographics.

7 CONCLUSION

We present a virtual body-swapping system that allows multiple users to embody their personalized photorealistic avatars and to switch perspectives with other users in real-time. In our evaluation with 20 participants, we address the effect of a virtual body swap on the sense of virtual embodiment (SoE) toward one's personalized and swap avatar. We further connect this SoE to other self-related processes during the experience, including interoceptive awareness and self-compassion. Our results show that, while bottom-up processes of SoE pass over to the new avatar, the top-down self-identification remains with the personalized avatar even after the body swap. We further could show that while self-compassion remained unaffected, participants' interoceptive awareness was slightly increased after the body swap. Finally, we define a set of affordances for future research and design in the context of body swap-based virtual mind-body interventions. Virtual body swap experiences can be an innovative milestone for all interventions that work with perspective change. Our work sets an important stepping stone for the future design of such systems.

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