Bridging Experimental and Clinical Settings: Usability and User Experience of Virtual Reality Body Swapping for Body-Focused Interventions.

Giulia Brizzi, Andrea Signorelli and Giuseppe Riva

April 25, 2024

Bridging Experimental and Clinical Settings: Usability and User Experience of Virtual Reality Body Swapping for Body-Focused Interventions

Giulia Brizzi[1], Andrea Signorelli[2], and Giuseppe Riva[1,3,4]

[1] Applied Technology for Neuro-Psychology Lab, IRCCS Istituto Auxologico Italiano, Via Magnasco 2, 20149, Milan, Italy
[2] Department of Electronic Informatic Biomedic Engineering, Politecnico di Milano, Piazza Leonardo da Vinci, 32 20133 Milano
[3]Humane Technology Laboratory, Università Cattolica del Sacro Cuore, Largo Gemelli, 1, 20121 Milan, Italy
[4] Department of Psychology, Università Cattolica del Sacro Cuore, Largo Gemelli, 1, 20121 Milan, Italy

Abstract.
In recent years, many attempts have been to develop new approaches to treat mental disorders using Virtual Reality technology. Because of its properties, Virtual Reality emerged as a suitable tool to study body experience thanks to paradigms such as Body Swapping (VR-BS). Preliminary data revealed that VR-BS was able to assess and treat altered body experience in conditions such as Anorexia Nervosa. However, the application of VR-BS in clinical settings is hindered by the complexity of the technology, which often requires specialized expertise and can induce cybersickness. This study introduces an open-source VR-BS system designed to minimize technical barriers and enhance usability and user experience for both practitioners and participants. By involving participants in both patient and experimenter roles, we conducted a mixed-method evaluation of the system's usability and user experience. Data indicate high usability and positive user experiences, highlighting the system's potential applicability in clinical practice by both non-expert clinicians and patients. This study not only supports the feasibility of implementing VR-BS in therapeutic contexts but also provides critical insights into design and operational strategies that facilitate the integration of VR technology in clinical settings. By bridging the gap between experimental research and clinical practice, our work underscores the transformative potential of VR in developing effective assessment, prevention, and intervention protocols that leverage the unique advantages of virtual reality for mental health treatment.

Keywords: Multisensory Integration, Body, Virtual Reality, Body Illusion, Anorexia, Body Swapping, Usability, User Experience, Allocentric, Mirror Exposure.

1 Introduction

In recent years, there have been many attempts to develop new approaches to promote psychological well-being and treat mental disorders using technological advances, especially in the realm of Virtual Reality (VR).

VR is an embedded, cognitive, and multisensory technology that works similarly to the human brain: it creates and maintains a model of the user's body and the surrounding environment (embedded), and adapts the output (multisensory) based on the user's input (cognitive; [1,2]. Due to these specific characteristics, VR has been increasingly used in different areas of psychology to better understand the human mind. Among them, one area that has particularly benefited from this technology is that of bodily experience.

Bodily experience is a complex process requiring the integration of information from different sensory modalities (e.g., visual, tactile, sensorimotor) and spatial frames (i.e., first and third-person perspectives) into a single and coherent percept [3]. That is, how we experience our bodies derives from a Multisensory Integration process [3,4].

Because of its properties, VR emerged as a valid tool to study such a complex phenomenon, thanks to paradigms such as Body Illusions [5]. In Full-Body Illusions (FBI), individuals experience an entire virtual body as their own due to the spatiotemporal synchronization between the real and the artificial bodies [6]; that is, for instance, the synchronization between individuals' movements and those of the avatar makes them perceive the virtual body as their own, thus producing embodiment over the artificial body. Essentially, the multisensory correspondence between what a person feels, performs, and sees in the physical and virtual environment fosters a sense of ownership, agency, and self-location toward the artificial body, significantly altering Body Self-Consciousness [7].

Notably, further research revealed that embodiment can occur even when the virtual body significantly differs from the physical form, as demonstrated by the Body Swapping (BS) illusion [8]. During BS, individuals experience embodiment over a completely different body as compared to the real one. Several research observed that individuals could embody a taller or a thinner body as compared to their one [8,9] and that this influenced body representation and how they interact with the surrounding environment [10]. Then, Body illusion in VR offers a unique opportunity to better understand the mechanisms underlying body experience, revealing how it can be easily manipulated.

1.1 Body-focused Interventions in Virtual Reality

VR offers the opportunity to immerse oneself in an alternative reality and experience scenarios that are otherwise only achievable via imagination. Given this possibility, the use of avatars has attracted attention in the treatment and assessment of body-related disturbances [11-13]. Specifically, this gave rise to new possibilities in the field of disorders characterized by body-self disturbances, such as Anorexia Nervosa (AN). Patients affected by AN indeed reliably report being dissatisfied with their bodies and show a limited ability to correctly perceive their bodies in terms of size and shape [14]. Remarkably, this body-self alteration seems to play a key role in the onset and maintenance of AN symptomatology, so it became a key aspect to work on to improve current assessment, prevention, and therapeutical interventions [3].

Body Swapping in Virtual Reality (VR-BS) emerged as a promising tool to correct this altered body-self relationship [15-17]. Initial findings indicate that allowing patients with AN to experience being in a different body through a first-person (egocentric) perspective reduces inaccuracies in their perception of their own body's size [18,19]. More recent procedures for body-self interventions aim instead for enhanced mirror confrontation [11]. They surpass real mirror confrontation by modifying the mirror image or the shown avatars into different body shapes. In this regard, research observed that experiencing a normal-weight body from a third-person (allocentric) perspective - akin to viewing oneself in a mirror - has been shown to positively influence symptoms such as the fear of gaining weight in patients affected by AN [15-17].

Current literature endorses the application of VR-BS for addressing body-self relationship issues, highlighting VR's potential as a significant enhancement in mental health care [20]. Despite its promise, the practical deployment of VR-BS beyond research environments remains limited. This limitation is partly due to the complexity of VR technology, which involves sophisticated hardware and software that are not widely accessible and typically demand specialized knowledge to operate.

Before introducing a VR system into clinical practice, testing the usability and user experience (UX; [21]) of the system itself is needed. Usability focuses on how easily a product can be used to achieve its intended purpose, while UX encompasses the user's subjective responses to using the product, such as satisfaction, engagement, and enjoyment [22]. This evaluation is essential to ensure the system operates smoothly without negatively affecting the intervention's success or causing user discomfort (e.g., cybersickness; [23]). It's also vital to confirm that the system is intuitive and enjoyable for users, including both the healthcare professionals administering it and the patients experiencing it. Despite the limited research on user experience and usability of VR-BS systems, we argue that their integration into clinical practice necessitates user-friendly interfaces for healthcare professionals and comfort for patients as a fundamental prerequisite.

In this study, we developed and assessed a VR-BS system's usability and user experience from the perspectives of both the administrator and the participant using qualitative and quantitative methods. We expected an overall good usability level and positive user experience from both conditions; though, we expect to gain useful insights to improve the system so that it will have the necessary qualities for being clinically relevant and easy to use by non-technical users. The final goal is to propose an open-source tool that balances technical and clinical requirements.

2 Methods

Participants

A total of 20 female participants participated in the study (mean age = 25.35, sd = 3.759). None of them disclosed having a current or previous diagnosis of neurological or eating disorders. Out of these, 12 participants had no prior experience with Virtual Reality technology.

Procedure
The study procedure is divided into four phases. Figure 1 shows a graphic representation of the procedure.

Phase 1. Participants were briefly introduced to the means and aims of the research and, afterward, they completed a questionnaire gathering socio-demographic information and the Cybersickness Scale Questionnaire to assess symptoms and discomfort before the virtual experience.

Phase 2: Subject condition. Participants engaged in the Virtual Reality Body Swapping (VR-BS) experience. They began by standing in front of a Kinect motion-tracking camera and donning a VR headset. The experimenter then calibrated the system to align the participant's real body with their virtual avatar. To promote embodiment, the experimenter applied tactile stimulation to the participant's abdominal area using a controller, which was coherently replicated on the avatar's abdomen for 90 seconds [19]. Following the visuo-tactile synchronous stimulation - from a 1st person perspective - participants assessed their level of embodiment using a Visual Analogue Scale (VAS; [15]). They then observed their virtual body in a mirror within the VR environment - from a 3rd person perspective - which tracked them in real-time with their movements. Throughout this experience, participants verbalized their thoughts about the system, including opinions, advice, and questions (Think Aloud Method; [24]). After completing the VR-BS experience, participants filled out questionnaires to evaluate their sense of presence within the virtual environment (Presence Questionnaire; [25]), their overall user experience (User Experience Questionnaire; [26]), and any symptoms of cybersickness experienced during the session (Cybersickness Scale Questionnaire; [27]).

Phase 3: Experimenter Condition. In this phase, the roles were reversed to assess the system's usability from the experimenter's viewpoint. Initially, participants were introduced to the functionalities of the controller used during the VR-BS experience. Subsequently, they assumed the role traditionally held by the experimenter, while the actual experimenter acted out the role of a participant. This role reversal was designed to evaluate the system's usability more comprehensively by having participants replicate the actions performed by the experimenter in Phase 1 (e.g., calibrating the avatar and administering tactile stimulation to the abdominal area, inserting the mirror). The participant can see what happens in the virtual environment by looking at the computer. Task success was documented using a Task Analysis grid [28], which helped in identifying any operational challenges or areas for improvement. Again, participants were encouraged to verbalize doubts, concerns, or suggestions they had regarding the system (employing the Think Aloud Method). This feedback was crucial for understanding the system's usability from a new user's perspective, particularly one with responsibilities akin to those of an experimenter. After completing the role-reversal tasks, participants were asked to fill out the System Usability Scale questionnaire [29]. This tool was specifically chosen for this phase to evaluate the system's usability, considering that the participants' role in this condition was more active and involved compared to their relatively passive role in the "participant condition." The consistent presentation order of Phases 2 and this experimenter condition ensured that all participants had a similar experience and basis for their evaluations.

Phase 4: Debriefing. Lastly, there was a debriefing in which participants asked questions and expressed their considerations, opinions, and a personal evaluation of the experience.

The total duration of the experiment was approximately 45 minutes.

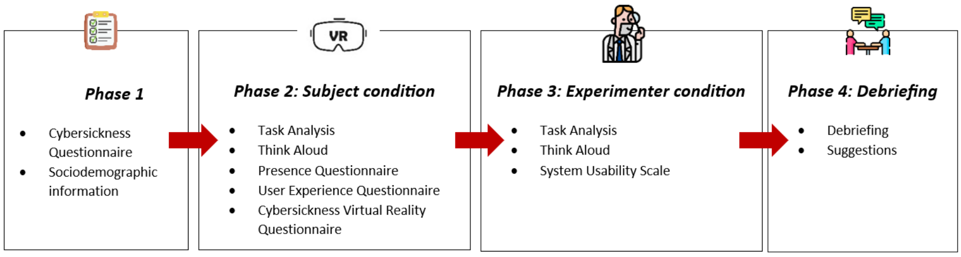


Fig. 1 Procedure. The figure shows the experimental design.

Body Swapping in Virtual Reality (VR-BS)

We developed a Virtual Reality Body Swapping (VR-BS) experience that allows participants to view a normal-weight- avatar (waist-to-height ratio equal to 0.4606) from both a first-person (egocentric) and a third-person (allocentric, mirror-like) perspective, building upon the findings of previous research [15-17]. The avatar was crafted using the MakeHuman software (www.makehumancommunity.org), incorporating body measurements from earlier studies [18,19]. To minimize potential anchoring effects, the avatar is situated in a neutral room, created with Unity 3D software (www.unity3d.com). The application is compatible with the Oculus Quest 2 headset, requiring a connection between the headset and a computer. During the experience, one controller is provided to the participant and another to the experimenter. An initial scene facilitates embodiment by aligning the experimenter's controller with a virtual ball, enabling the experimenter to touch the avatar's and participant's abdominal areas synchronously (Embodiment). The experimenter can add or remove the ball from the scene. Subsequently, participants can become accustomed to the motion tracking system and observe the synchronization between their movements and those of the avatar, facilitated by the Azure Kinect (Familiarization). The experimenter can then administer a Visual Analogue Scale to assess the degree of embodiment (as detailed in research by [15-17]; Embodiment Questionnaire). Additionally, the experimenter can introduce or withdraw a mirror to switch between viewing the avatar from a first-person perspective (without the mirror) or a third-person perspective (with the mirror). In the mirror-like scenario, participants can see the avatar from the neck down to avoid the uncanny valley effect (i.e., when a computer-generated figure that bears a near-identical resemblance to a human being evokes a sense of unease or revulsion in the viewer; [32]) and enhance self-projection. Fig. 2 illustrates the system's key features.

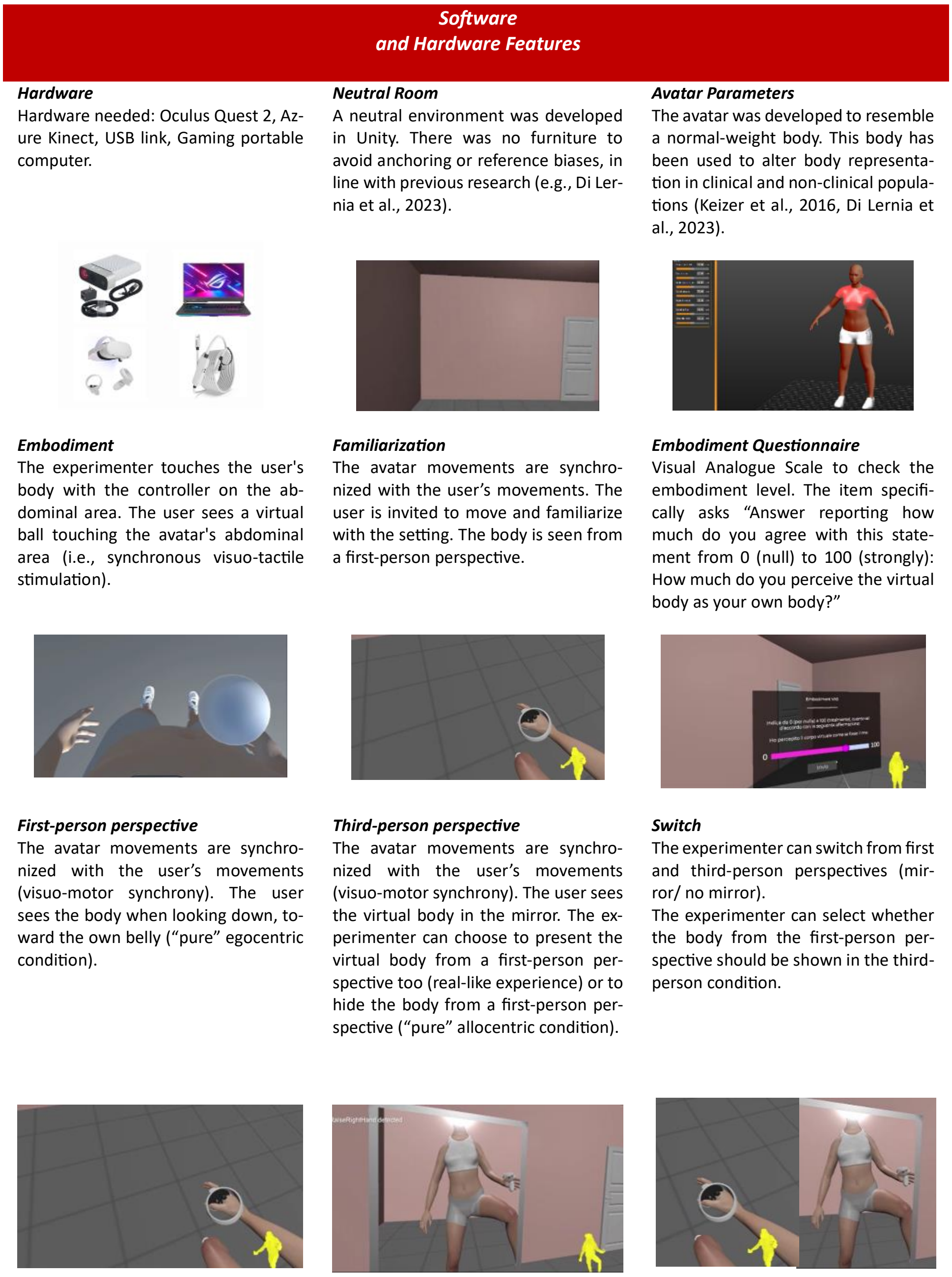


Fig.2 System main features design and implementation. Embodiment refers to the classical visuo-tactile stimulation to promote a sense of embodiment over the virtual body; Familiarization refers to a first approach with the motion tracking system; Embodiment Questionnaire

refers to the Visual Analogue Scale to measure embodiment strength [15-17]; First- and Third-person perspective refers to the experience with and without the mirror (based on [15-17]).

Usability Measures

System Usability Scale (SUS; [29]): The SUS is a “quick and easy to use” questionnaire to assess interfaces and system usability. It consists of 10 items to which the subject must respond according to a Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). It has proven to be a valuable, robust, reliable evaluation tool for evaluating a wide range of technologies. The final score ranges from 0 (lack of usability) to 100 (optimal usability). The scores were interpreted according to the 7-point adjective rating scale consisting of the following levels: 'best imaginable', 'excellent', 'good', 'OK', 'poor', 'dreadful', and 'worst imaginable'. Specifically, scores higher than 68 indexed a good usability level.

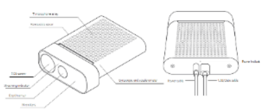
Presence Questionnaire (PQ; [25]): The PQ measures the sense of presence. It consists of 24 items to be answered by the subject on a Likert scale from 1 (null) to 7 (completely). The questionnaire analyses various aspects of the sense of presence: specifically, the level of realism, the possibility of acting, interface quality, the possibility of examining, self-assessment of performance, sounds, and tactile feedback.

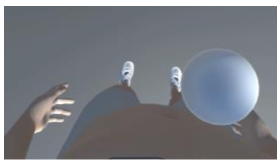
Cybersickness Scale Questionnaire – Virtual Reality (CSQ-VR; [27]): The CSQ-VR measures symptoms and burdens related to immersive VR experiences and the use of the VR headset. It consists of a 7-point Likert scale (1 = absent to 7 = very much) comprising 6 questions for the assessment of the three core symptoms typically related to cybersickness (i.e., nausea, vestibular, and oculomotor symptoms).

Task Analysis [28]: Task Analysis is an observational method that involves the analysis of the activities, tasks, and subtasks that users must perform to achieve one or more objectives when interacting with a system. It allows the identification of critical and strong points of the human-system interaction. Key steps of the interaction between the user and the system were identified (Fig.3) and the experimenter reported whether the user was able to perform the task or not, or whether encountered difficulties.

Task participants had to complete

Connect the Kinect	***Launch the app***	***Stimulation***
Connect the Azure Kinect to the computer for the motion tracking system.	Launch the VR application on the computer.	Use the controller the control the virtual ball and apply the visuo-tactile stimulation over the abdominal area of the virtual and real body.





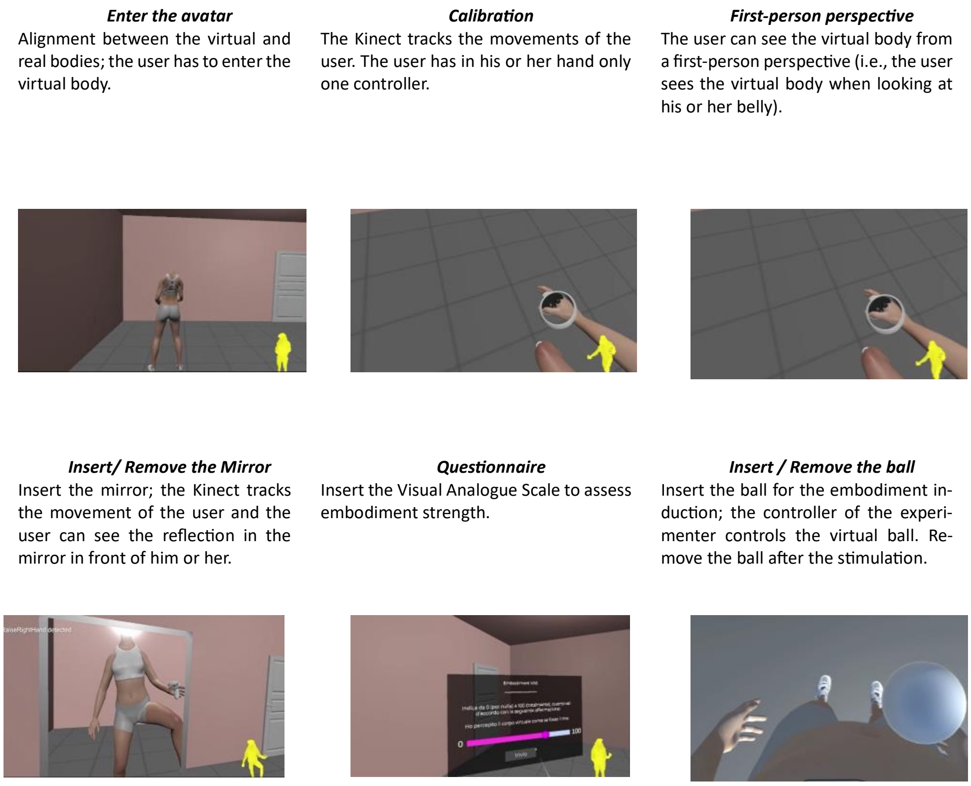


Fig.3 Task Analysis core steps. Participants were instructed to mimic the core procedures commonly employed in the application of body swapping within a clinical context [15].

User Experience Measures

User Experience Questionnaire (UEQ; [29]): the User Experience Questionnaire is a standardized questionnaire used to evaluate the user experience of interactive products such as software or online tools. The UEQ contains 6 scales with 26 items covering a comprehensive impression of the user experience. The scales cover both classical aspects of usability (efficiency, perspicuity, reliability) and aspects of user experience (originality, stimulation, and attractiveness). The UEQ was designed with opposing adjectives as items for each domain, to be answered by the subject on a Likert scale from 1 to 7.

Think-Aloud Method [30]: The think-aloud method is a qualitative method used to assess usability when a new technology is developed. Users are asked to report their opinions regarding the technology and criticism while interacting with the device/software. The experimenter was asked to take notes or to record the participants' observations, which could include what they were looking at, thinking about, doing, and feeling. All the verbalizations were transcribed into a reporting grid and analyzed with thematic analysis to develop the formal usability report.

3 Analysis and Results

3.1 Experimenter condition

System Usability Scale

The participant's scores for each question were added together and then multiplied by 2.5 to convert the original scores of 0-40 to 0-100. The total SUS score of the proposed system was 70.25 (sd = 6.3815), thus indicating good usability. Fig. 4 shows the SUS scoring interpretation.

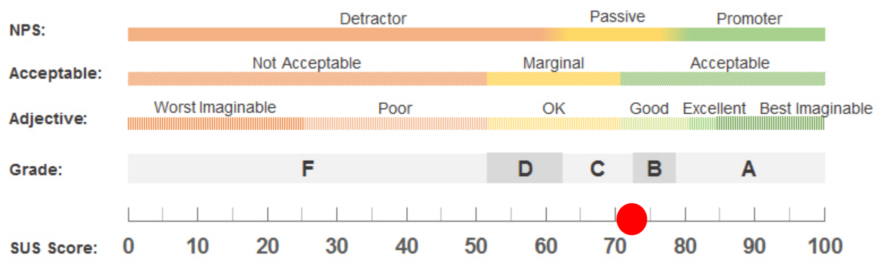


Fig. 4 SUS scoring interpretation. Grid to interpret SUS total score. The red dot represents the mean score obtained by the proposed system (image from https://measuringu.com/interpret-sus-score/).

Task Analysis

During the interaction with the system, the experimenter reported whether the participant was able to complete the task. The percentage of task success was then calculated for each subtask to identify critical points (Fig. 5). Task completion was categorized based on previous usability studies (i.e., Successfully completed =1, Partial, =0.5, Unsuccessful = 0; [28]). The analysis revealed difficulties in the alignment and calibration tasks. Participants found it demanding to align the virtual and real bodies and specify the Kinect to track the users' movement. Notably, such difficulty was higher for participants without previous experience with VR. However, complications decreased the second time calibration was performed. The reasons underlined observed difficulties were then clarified by think-aloud reports. All the other tasks instead were correctly performed by all participants.

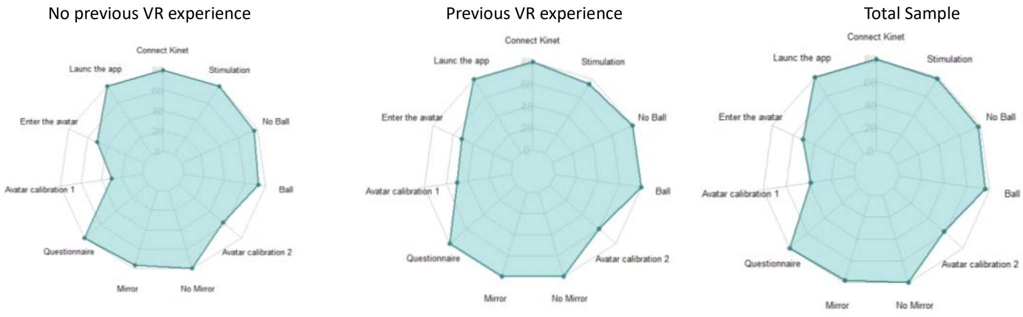


Fig. 5 Task Analysis Results. The graph shows the results of the task analysis in terms of the success rate, both concerning the previous Virtual Reality experience as well as the sample. Labels: launch the application, connect Kinect, abdominal stimulation, insert the ball, remove the ball, calibrate the avatar two times, insert the mirror, remove the mirror, questionnaire, and enter the subject in the avatar's body.

Think Aloud

The thematic analysis of participant reports indicated that most of the users initially experienced anxiety about potentially damaging the system, expressing specific concerns about breaking the controller or computer. This apprehension decreased as they grew more accustomed to the system and gained confidence in their ability to execute the necessary tasks. The challenges identified through task analysis concerning the alignment and calibration tasks primarily stemmed from difficulties in memorizing the commands and buttons. A common mistake was the inadvertent pressing of the trigger button instead of the intended lateral one, with some participants resorting to pressing the trigger or other buttons randomly when they did not remember what to do.

Some of the participants' comments were:

"I automatically click on random buttons", "I feel a little bit scared", "I think trying the experience as a subject before is essential to understand what to expect", "I guess that trying the system two or three times will be sufficient to be more confident", "I am scared that something will go wrong and I do not know how to fix it", "How to align the body?", "I click on random buttons when I do not remember what to do", and "I automatically click on the trigger button".

In response to these issues, participants recommended system improvements. One suggestion was to reassign specific functions, such as alignment and calibration, to different buttons to avoid confusion. Additionally, there were proposals for providing users with a checklist or guidelines to facilitate easier navigation through the system's functions.

3.2 Participant condition

User Experience Questionnaire

UEQ scores revealed notable variations across different scales of users' perceptions. For the scale of Attractiveness, the mean score was 1.883 (sd= 0.401, CI [1.707; 2.059]), indicating a high level of attractiveness. In the domain of Perspicuity, the mean was 0.550 (sd = 0.536, CI [0.315; 0.785]), suggesting variability in clarity or understandability. Efficiency was scored with a mean of 0.925 (sd = 0.414, CI [0.743; 1.107]) reflecting an average efficiency perception. Similarly, Dependability had a mean score of 0.925 (sd = 0.460, CI [0.724; 1.126]) indicating participants' relative confidence in the system's reliability. Stimulation and Novelty showed mean scores of 2.213 (sd = 0.552, CI [1.971;2.454] and sd = 0.482, CI [2.001; 2.424] respectively), indicating above-average levels. Figure 6 shows UEQ results.

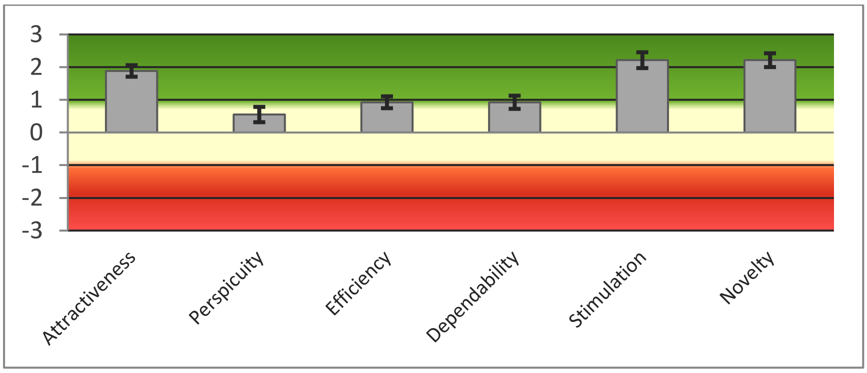


Fig. 5 User experience after VR exposure. The figure shows UEQ scores for each subscale. The colors (green, yellow, and red) indicate above, within, and below average thresholds. The bar chart shows the means and standard deviations obtained in the six different qualities of the VR system.

Presence Questionnaire

Sense of presence within the virtual environment was overall highly rated. The "Possibility to Act" was rated with a mean value of 24.0 (sd = 2.11), indicating a strong sense of agency experienced by participants. In terms of "Quality of Interface," participants reported a mean value of 19.7 (sd = 0.856), reflecting a high degree of satisfaction with the interface. The "Possibility to Examine" achieved a mean value of 13.4 (sd = 2.26), suggesting that participants felt the ability to explore and interact with the environment in a meaningful way. The "Self-evaluation of Performance" garnered a mean value of 10.1 (sd = 1.52), pointing good level of perceived effectiveness in navigating and manipulating the virtual environment. The "Haptic" feedback dimension had a mean value of 4.6 (sd = 1.64). Remarkably, the "Realism" factor scored the highest mean value of 42.3 (SD = 3.29), significantly enhancing the overall sense of presence for users. Collectively, these dimensions contributed to a total mean value of 71.8 (SD = 3.29), encapsulating the participants' overall sense of presence within the virtual environment.

Cybersickness Virtual Reality Questionnaire
None of the participants reported symptoms before and after the virtual reality experience. CSQ-VR mean score was 0 both before and after the virtual reality experience.

Think Aloud
The thematic analysis of participant reports revealed participants' perceptions of a high-quality, immersive, and engaging experience. They underscored the role of movement synchronization in fostering a sense of ownership over the virtual body, with many reporting moments where they felt completely absorbed by the virtual environment, to the extent of momentarily forgetting their real bodies. The experience of seeing their reflection in a virtual mirror was highlighted as particularly impactful, creating a profound sense of connection with the virtual avatar.

Participant comments included:

"The graphics and synchronicity exceeded my expectations.", "The virtual environment was simple yet realistic enough to make me forget about the real world at some point.", "I found myself automatically moving at the beginning just to verify the body was indeed mine.", "The synchronization was impressive: super-fluid and realistic, responding accurately in all directions."

Participants also voiced some criticisms. For example, they expressed a desire for more interactive elements, such as the ability to engage with other virtual people or objects and to move freely around the room. One of them reported preferring the experimenter to be present in the virtual environment too, to avoid the experimenter's voice being outside the virtual environment. Two participants noted occasional calibration issues, resulting in slight latency between their movements and those of the avatar, and instances where the virtual ball malfunctioned.

4 Discussion

Virtual reality (VR) stands at the forefront of technological advancements, offering a gateway into alternate realities that were once confined to the boundaries of the imagination. As an immersive, cognitive, and multisensory platform, VR has the unparalleled capability to forge deeply engaging experiences that are instrumental in exploring and understanding the intricacies of the human mind [2]. Such capabilities are particularly transformative in clinical settings, where VR's potential to alter bodily perceptions holds promising implications for conditions associated with distorted body-self relationships [12,13].

Among the most groundbreaking applications of VR is the Body Swapping (BS-VR) illusion, which empowers individuals to inhabit an alternate body, thereby altering their physical self-perception. This approach offers a novel method for patients to reconceptualize their bodies, providing a potential therapeutic avenue for conditions like Anorexia Nervosa (AN; [5]).

In this study, we introduced a BS-VR system that enables swapping into another body from both first-person (egocentric) and third-person (allocentric) perspectives, building upon the foundation laid by previous research [15-17]. We specifically evaluated the user experience and usability of the proposed system. This focus diverges from prior research by encompassing the perspectives of both the recipients of the VR experience and the administrators, thereby offering a comprehensive understanding of the system's practicality in clinical and therapeutic settings.

Results from the experimenter and subject conditions will be discussed in the next sections with related virtual reality design advice.

4.1 Experimenter Condition

In the experimenter condition participants assumed the role of the experimenter and administered the VR experience firsthand. Most of the participants initially expressed apprehension about using the system, fearing they might damage it. This emotional obstacle and fear of technology [34] might account for resistance to Virtual Reality applications in clinical settings. However, this concern diminished as they became more familiar with the system, reinforcing the importance of practice in building confidence and self-competence [35]. These data suggest that familiarization and training phases are critical for the adoption of technological devices and should be taken carefully into account when proposing new systems [36] .

This was confirmed also by task analysis. Indeed, participants with previous experience performed slightly better than those without previous experience with VR. That is, technical and specific experience in the VR-BS influenced the system's successful implementation. Notably, participants with previous experience did not present a high level of knowledge (e.g., they reported having tried VR in previous experiments) meaning that little expertise might be sufficient to appropriately use the system. In line with this consideration, the task analysis revealed that participants were more adept at performing alignment and calibration tasks independently on their second attempt.

Moreover, participants expressed the need for initial hands-on experience with the system to fully grasp what to expect and how to navigate the experience. They appreciated the subject's experience before having to play the role of the experimenter because this allowed them to understand if they were doing right and if everything was working as intended. In this regard, participants appreciated the possibility of seeing what the subject sees in the headset by computer, possibly because this enhanced their feeling of control over the technological device [37]. Then, good usability results might be linked to the condition presentation order. Future studies might also consider reversing and counterbalancing the conditions to better investigate usability. That is, half of the participants might start trying the system as a subject while the others have written instructions. This might reveal additional insights in terms of design optimization.

Going more into detail, task analysis uncovered specific challenges related to the calibration and alignment of the physical body with the virtual avatar. Participants struggled with manually aligning the virtual and physical bodies and correctly setting up the motion-tracking system. Qualitative feedback revealed difficulties in remembering specific commands or inadvertently pressing the trigger button in terms of design and programming, this suggests that critical commands should not be assigned to the trigger button to prevent unintentional modifications of the experience. Moreover, it suggests the potential benefits of automating tasks to minimize the cognitive load of remembering multiple commands.

Despite initial concerns, the System Usability Scale indicated that the system was generally considered user-friendly. Then, different from previous systems [38], our system was rated as easy to use by both users with and without previous experience with Virtual Reality technology.

Based on results and previous research [38, 39], some VR design suggestions were extracted (Table 1).

Table 1. Virtual Reality design suggestions for body illusion protocols.

	Suggestions
Familiarization and Training	• Implement comprehensive training sessions to familiarize with the VR system before actual use. This helps in overcoming initial apprehensions and builds confidence and self-competence. • Provide hands-on experience as part of the training to help users grasp the system's functionality and navigation, enhancing their preparedness for the actual application. • Incorporate features that allow administrators to see what the subject sees through the headset on a computer to increase the feeling of control over the device.
Systema design and Calibration	• Simplify the alignment and calibration process between the physical and virtual bodies. • Consider automation of tasks to reduce the cognitive load on users. • Avoid assigning critical commands to buttons that can be easily triggered unintentionally. Explore alternative interaction methods to prevent accidental modifications of the experience.
Support and Documentation	• Provide clear and comprehensive documentation and support materials, including troubleshooting guides, to assist users in overcoming challenges related to system use and calibration.

4.2 Subject Condition

In the subject condition, participants were introduced to the virtual reality experience by the experimenter. A key finding is that the system, despite involving movement with a motion tracking system, did not cause discomfort or cybersickness, regardless of whether participants had previous virtual reality experiences or were first-time users [38]. This outcome was consistent with the VR exposure limited duration, aligning with the typical duration of a VR intervention protocol (e.g., [15]. While some preliminary studies have explored the user experience of body swapping in a clinical sample of patients with anorexia, they did not account for this variable [36]. However, discomfort related to the equipment might play a crucial role in the adoption of this technique in clinical practice, especially for vulnerable individuals [39].

In terms of UX, there was a positive evaluation of the experience in both the questionnaire and the participant reports. All scales on the questionnaire were rated average or above average according to standard parameters. Notably, the scales for attractiveness (overall impression of the system), novelty (impression that the product design and idea are creative and original), and stimulation (impression that using the product is interesting and fun) scored above average. From the qualitative data, we observed that most participants were pleasantly surprised by the graphic quality, level of immersion, and accurate movement tracking. For instance, participants reported, "I got a much higher quality than I expected: that was impressive," and "It was my first time with this type of experience, and I did not expect it would be so engaging and immersive."

For the remaining scales—Perspicuity (ease of learning how to use the product), Efficiency (impression that tasks can be completed without unnecessary effort), and Dependability (feeling in control of the product interaction)—the results were lower but still within the average range. The qualitative data helped identify possible reasons for this. For example, many participants expressed fear of breaking something or damaging the system, while others felt intimidated by their first virtual reality experience and were unsure what to expect. Additionally, some participants did not understand the purpose of the ball procedure. Overall, however, the experience was positive and engaging for all participants. This finding is particularly significant considering the clinical application in conditions characterized by a lack of therapeutic alliance, reduced compliance, and strong resistance [42], with ego-syntonic symptoms such as Anorexia Nervosa [43]: finding procedures that can break down the barrier between therapist/clinician and patient is even more crucial in these cases.

As for the sense of presence, the questionnaire showed high levels of immersion and presence in the virtual environment, confirmed by qualitative data. For example, some participants noted, "The part with the mirror especially was impressive: I thought that I was looking at myself," "I have tried the previous version without the motion synchronization, and the feeling of owning the artificial body wasn't as strong. I understand what immersive means now: it was like I was in another time and space." This is particularly important as presence might significantly contribute to the efficacy of VR interventions [46].

These comments clarify that movement was a critical component in promoting a sense of presence and embodiment. This aligns with the sensorimotor theory of perceptual experience, suggesting a critical role of bodily interaction with the environment in shaping perception [45,46] and the sensorimotor foundation of Bodily Self-Consciousness [47]. In terms of design, static procedures like those used by [8, 18] might be therefore sub-optimal, and dynamic experiences should be preferred.

Based on results and previous research [38, 39], some VR design suggestions were extracted (Table 2).

Table 2. Virtual Reality design suggestions for body illusion procedures.

Suggestions

Minimize Discomfort and Cybersickness	• Limit the duration of VR interventions with the typical length of VR exposure: shorter sessions (around 20-30 minutes) can help maintain user comfort and engagement without inducing fatigue and cybersickness.
Emphasize Quality and Immersion	• Invest in high-quality graphics and accurate motion tracking systems to enhance the sense of presence (physical and psychological presence/ immersion).
Simplify Learning and Interaction	• Design interfaces that facilitate easy learning and efficient task completion. • Addressing fears of damaging the system and clarifying the purpose of specific procedures (like the ball procedure) can improve perspicuity, efficiency, and dependability.
Maximize Presence and Embodiment	• Leverage dynamic experiences that promote a strong sense of presence and embodiment, as movement and sensorimotor interaction are key to these sensations. • Prefer dynamic experiences, as they are more effective than static procedures in promoting bodily self-consciousness and a sense of presence.

In the present study, we did not investigate user-experimenter interaction. However, this might be an important factor in determining the overall user experience. Future research might better focus on more specific aspects of the VR-BS experience such as tactile stimulation. In particular, the intensity and direction of tactile feedback could have a significant impact on users' sense of embodiment and the overall effectiveness of the intervention. This is especially true for sensitive areas such as the abdomen, which can cause discomfort for some participants and potentially detract from the experience. Consequently, further research could explore the implementation of targeted tactile stimuli – e.g., affective touch [48] – to evaluate its impact on the user experience and embodiment induction.

Limitations

The current study, while insightful, encounters several limitations that warrant discussion. First and foremost, the relatively modest sample size poses a constraint. Despite aligning with recommended norms for usability and user experience research as suggested by [50,51], the sample size may still limit the generalizability of our findings. Nonetheless, the data's consistency lends credence to our conclusions, suggesting a minimal likelihood of uncovering new critical factors with a larger cohort. Our system's development and evaluation were meticulously designed with a focus on ethical considerations, particularly given its intended future application in clinical settings. This formative evaluation with healthy participants lays the groundwork for subsequent studies involving potential patients, as part of a broader feasibility study aimed at clinical implementation [41].

Looking ahead, future research should aim to include a broader spectrum of participants, encompassing both clinical populations and healthcare professionals. This expansion is critical for validating our findings within therapeutic contexts. Moreover, the feedback regarding system limitations, especially the challenges related to calibration and alignment tasks, underscores the need for enhancements. Automating these processes could significantly improve user-system interaction, echoing the principles of iterative design where user feedback drives system refinement [48].

The necessity for effective communication between therapists and users, which may intermittently disrupt the sense of presence, raises important questions regarding the overall impact of presence in body image interventions. This consideration is equally pertinent to augmented reality applications [51].

Finally, due to the aim of this study, we only implemented one body, but the next development requires the introduction of different body sizes and shapes to cover a spectrum from underweight to overweight, in line with previous protocols (e.g. [16]).

Conclusion

This study introduces a pioneering open-source virtual reality (VR) software, designed to facilitate the body-swapping illusion protocol for a wide range of applications, from assessment to therapeutic interventions across non-clinical, sub-clinical, and clinical populations [19]. Specifically, it addresses the needs of individuals experiencing altered body perceptions, such as those suffering from Anorexia Nervosa (AN). Our findings reveal the feasibility of employing an affordable VR setup—comprising a head-mounted display, a laptop, and a webcam—to immerse users in a virtual environment where they can embody a virtual avatar different from their physical one. A distinctive feature of the proposed VR system is its support for both egocentric (first-person) and allocentric (third-person, mirror-like) perspectives, enriching the user's engagement with and exploration of bodily experiences.

Contrary to prior research, our application has been well accepted in terms of usability and user experience by both participants and administrators. With minor modifications, this system emerges as a well-balanced tool that satisfies both technical and experimental demands, ensuring accessibility for users and practitioners outside the technical domain.

We contend that such analytical approaches are crucial for crafting effective tools aimed at exploiting Multisensory and Embodied VR technology to promote Transformative Experiences (METE), namely immersive experiences that significantly impact an individual's perception, cognition, and emotional state, fostering a profound personal and psychological transformation. This work not only bridges the gap between experimental and clinical domains but also harnesses technological advances to improve prevention and intervention strategies. Ultimately, this study highlights the potential of VR technologies to create powerful, accessible, and user-friendly platforms for addressing complex psychological conditions, paving the way for innovative therapeutic solutions.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Malighetti, C., Sansoni, M., Gaudio, S., Matamala-Gomez, M., Di Lernia, D., Serino, S., & Riva, G. (2022). From virtual reality to regenerative virtual therapy: some insights from a systematic

review exploring inner body perception in anorexia and bulimia nervosa. Journal of Clinical Medicine, 11(23), 7134.
2. Riva, G., Serino, S., Di Lernia, D., Pavone, E. F., & Dakanalis, A. (2017). Embodied medicine: mens sana in corpore virtuale sano. Frontiers in Human Neuroscience, 11, 120.
3. Brizzi, G., Sansoni, M., Di Lernia, D., Frisone, F., Tuena, C., & Riva, G. (2023). The multisensory mind: a systematic review of multisensory integration processing in Anorexia and Bulimia Nervosa. Journal of Eating Disorders, 11(1), 204.
4. Brizzi, G., Sansoni, M., & Riva, G. (2023). The BODY-FRIEND Project: Using New Technology to Learn about How People with Anorexia Feel about Their Bodies. Cyberpsychology, behavior, and social networking, 26(2), 141-143.
5. Matamala-Gomez, M., Maselli, A., Malighetti, C., Realdon, O., Mantovani, F., & Riva, G. (2020). Body illusions for mental health: a systematic review.
6. Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: perceptual illusion of body swapping. PloS one, 3(12), e3832.
7. Matamala -Gomez, M., Donegan, T., Bottiroli, S., Sandrini, G., Sanchez-Vives, M. V., and Tassorelli, C. (2019). Immersive Virtual Reality and Virtual Embodiment for Pain Relief. Front. Hum. Neurosci.13, 279. doi:10.3389/fnhum.2019.00279
8. Serino, S., Polli, N., & Riva, G. (2019). From avatars to body swapping: The use of virtual reality for assessing and treating body-size distortion in individuals with anorexia. Journal of clinical psychology, 75(2), 313-322.
9. Malighetti, C., Chirico, A., Serino, S., Cavedoni, S., Matamala-Gomez, M., Stramba-Badiale, C., & Riva, G. (2020). Manipulating body size distortions and negative body-related memories in patients with Anorexia Nervosa: A virtual reality-based pilot study. Annual Review of CyberTherapy and Telemedicine.
10. D'Angelo, M., di Pellegrino, G., & Frassinetti, F. (2019). The illusion of having a tall or short body differently modulates interpersonal and peripersonal space. Behavioural Brain Research, 375, 112146.
11. Döllinger, N., Wolf, E., Mal, D., Wenninger, S., Botsch, M., Latoschik, M. E., & Wienrich, C. (2022). Resize me! Exploring the user experience of embodied realistic modulatable avatars for body image intervention in virtual reality. Frontiers in Virtual Reality, 3, 935449.
12. Horne, M., Hill, A., Murells, T., Ugail, H., Irving, D., Chinnadorai, R., et al. (2020). Using avatars in weight management settings: A systematic review. Internet Interv. 19, 100295. doi:10.1016/j.invent.2019.100295
13. Turbyne, C., Goedhart, A., de Koning, P., Schirmbeck, F., and Denys, D. (2021). Systematic review and meta-analysis of virtual reality in mental healthcare: Effects of full body illusions on body image disturbance. Front. Virtual Real. 2, 39. doi:10.3389/frvir.2021.657638
14. Gutiérrez-Maldonado, J., Ferrer-García, M., Caqueo-Urízar, A., & Moreno, E. (2010). Body image in eating disorders: The influence of exposure to virtual-reality environments. Cyberpsychology, Behavior, and Social Networking, 13(5), 521-531.
15. Porras-Garcia, B., Ferrer-Garcia, M., Serrano-Troncoso, E., Carulla-Roig, M., Soto-Usera, P., Miquel-Nabau, H., ... & Gutiérrez-Maldonado, J. (2021). AN-VR-BE. A randomized controlled trial for reducing fear of gaining weight and other eating disorder symptoms in anorexia nervosa through virtual reality-based body exposure. Journal of clinical medicine, 10(4), 682.
16. Porras-Garcia, B., Ferrer-Garcia, M., Serrano-Troncoso, E., Carulla-Roig, M., Soto-Usera, P., Miquel-Nabau, H., ... & Gutiérrez-Maldonado, J. (2020). Validity of virtual reality body exposure to elicit fear of gaining weight, body anxiety and body-related attentional bias in patients with anorexia nervosa. Journal of Clinical Medicine, 9(10), 3210.
17. Porras-Garcia, B., Ferrer-Garcia, M., Serrano-Troncoso, E., Carulla-Roig, M., Soto-Usera, P., Miquel-Nabau, H., ... & Gutiérrez-Maldonado, J. (2020). Validity of virtual reality body exposure to

elicit fear of gaining weight, body anxiety and body-related attentional bias in patients with anorexia nervosa. Journal of Clinical Medicine, 9(10), 3210.
18. Keizer, A., van Elburg, A., Helms, R., & Dijkerman, H. C. (2016). A virtual reality full body illusion improves body image disturbance in anorexia nervosa. PloS one, 11(10), e0163921.
19. Serino, S., Pedroli, E., Keizer, A., Triberti, S., Dakanalis, A., Pallavicini, F., ... & Riva, G. (2016). Virtual reality body swapping: a tool for modifying the allocentric memory of the body. Cyberpsychology, Behavior, and Social Networking, 19(2), 127-133.
20. Riva, G. (2017). Virtual reality in the treatment of eating and weight disorders. Psychological Medicine, 47(14), 2567-2568.
21. Bitkina, O. V., Kim, H. K., & Park, J. (2020). Usability and user experience of medical devices: An overview of the current state, analysis methodologies, and future challenges. International Journal of Industrial Ergonomics, 76, 102932.
22. Papakostas, C., Troussas, C., Krouska, A., & Sgouropoulou, C. (2021). Measuring user experience, usability and interactivity of a personalized mobile augmented reality training system. Sensors, 21(11), 3888.
23. Verkuyl, M., Romaniuk, D.K., & Mastrilli, P. (2018). Virtual gaming simulation of a mental health assessment: A usability study. Nurse education in practice, 31, 83-87 .
24. Eccles, D. W., & Arsal, G. (2017). The think aloud method: what is it and how do I use it?. Qualitative Research in Sport, Exercise and Health, 9(4), 514-531.
25. Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence, 7(3), 225-240.
26. Laugwitz, B., Held, T., & Schrepp, M. (2008). Construction and evaluation of a user experience questionnaire. In HCI and Usability for Education and Work: 4th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society, USAB 2008, Graz, Austria, November 20-21, 2008. Proceedings 4 (pp. 63-76). Springer Berlin Heidelberg.
27. Kourtesis, P., Linnell, J., Amir, R., Argelaguet, F., & MacPherson, S. E. (2023, January). Cybersickness in virtual reality questionnaire (csq-vr): A validation and comparison against ssq and vrsq. In Virtual Worlds (Vol. 2, No. 1, pp. 16-35). MDPI.
28. Annett, J. (2003). Hierarchical task analysis. Handbook of cognitive task design, 2, 17-35.
29. Laugwitz, B., Held, T., & Schrepp, M. (2008). Construction and evaluation of a user experience questionnaire. In HCI and Usability for Education and Work: 4th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society, USAB 2008, Graz, Austria, November 20-21, 2008. Proceedings 4 (pp. 63-76). Springer Berlin Heidelberg.
30. Eccles, D. W., & Arsal, G. (2017). The think aloud method: what is it and how do I use it?. Qualitative Research in Sport, Exercise and Health, 9(4), 514-531.
31. Brooke J. (1996). SUS: A 'quick and dirty' usability scale. In Jordan P.W., Thomas B., Weerdmeester A., McClelland I.I. (Eds.) Usability evaluation in industry, london (pp 189-194). Taylor & Francis.
32. Wang, S., Lilienfeld, S. O., & Rochat, P. (2015). The Uncanny Valley: Existence and Explanations. Review of General Psychology, 19(4), 393-407. https://doi.org/10.1037/gpr0000056
33. Marika Dy, Kristan Olazo, Courtney R Lyles, Sarah Lisker, Jessica Weinberg, Christine Lee, Michelle E Tarver, Anindita Saha, Kimberly Kontson, Richardae Araojo, Ellenor Brown, Urmimala Sarkar, Usability and acceptability of virtual reality for chronic pain management among diverse patients in a safety-net setting: a qualitative analysis, JAMIA Open, Volume 6, Issue 3, October 2023, ooad050, https://doi.org/10.1093/jamiaopen/ooad050
34. Juutinen, S., Huovinen, T., & Yalaho, A. (2011). Emotional Obstacle in E-learning-The fear of technology. International Journal for e-Learning Security (IJeLS), 1(3/4), 104-109.

35. Schank, R. C., Berman, T. R., & Macpherson, K. A. (2013). Learning by doing. In Instructional-design theories and models (pp. 161-181). Routledge.
36. Kalonde, G., & Mousa, R. (2016). Technology familiarization to preservice teachers: factors that influence teacher educators' technology decisions. Journal of Educational Technology Systems, 45(2), 236-255.
37. Deng, L., Turner, D. E., Gehling, R., & Prince, B. (2010). User experience, satisfaction, and continual usage intention of IT. European Journal of Information Systems, 19(1), 60-75.
38. Matamala-Gomez, M., Brivio, E., CHIRICO, A., Malighetti, C., Realdon, O., Serino, S., … Mantovani, F. (2020, July 10). User Experience and usability of a new virtual reality set-up to treat eating disorders: a pilot study. https://doi.org/10.31234/osf.io/b38ym
39. Döllinger, N., Wolf, E., Mal, D., Erdmannsdörfer, N., Botsch, M., Latoschik, M. E., & Wienrich, C. (2022, April). Virtual reality for mind and body: Does the sense of embodiment towards a virtual body affect physical body awareness?. In CHI Conference on Human Factors in Computing Systems Extended Abstracts (pp. 1-8).
40. Weech, S., Kenny, S., & Barnett-Cowan, M. (2019). Presence and cybersickness in virtual reality are negatively related: a review. Frontiers in psychology, 10, 158.
41. Kiryu, T., & So, R. H. (2007). Sensation of presence and cybersickness in applications of virtual reality for advanced rehabilitation. Journal of neuroengineering and rehabilitation, 4(1), 1-5. Ellrodt, A. G., Conner, L., Riedinger, M., & Weingarten, S. (1995). Measuring and improving physician compliance with clinical practice guidelines: a controlled interventional trial. Annals of Internal Medicine, 122(4), 277-282.
42. Ellrodt, A. G., Conner, L., Riedinger, M., & Weingarten, S. (1995). Measuring and improving physician compliance with clinical practice guidelines: a controlled interventional trial. Annals of Internal Medicine, 122(4), 277-282.
43. Gregertsen, E. C., Mandy, W., & Serpell, L. (2017). The egosyntonic nature of anorexia: an impediment to recovery in anorexia nervosa treatment. Frontiers in psychology, 8, 2273.
44. Gutiérrez-Martínez, O., Gutiérrez-Maldonado, J., & Loreto-Quijada, D. (2011). Control over the virtual environment influences the presence and efficacy of a virtual reality intervention on pain. Annual Review of Cybertherapy and Telemedicine 2011, 111-115.
45. Silverman, D. (2014). The sensorimotor theory of perceptual experience (Doctoral dissertation, University of St Andrews).
46. Ferri, F., Frassinetti, F., Ardizzi, M., Costantini, M., & Gallese, V. (2012). A sensorimotor network for the bodily self. Journal of cognitive neuroscience, 24(7), 1584-1595.
47. Ionta, S., Gassert, R., & Blanke, O. (2011). Multi-sensory and sensorimotor foundation of bodily self-consciousness–an interdisciplinary approach. Frontiers in Psychology, 2, 383.
48. Della Longa, L., Carnevali, L., Patron, E., Dragovic, D., & Farroni, T. (2021). Psychophysiological and visual behavioral responses to faces associated with affective and non-affective touch in four-month-old infants. Neuroscience, 464, 67-78.
49. Hwang, W., & Salvendy, G. (2010). Number of people required for usability evaluation: the 10±2 rule. Communications of the ACM, 53(5), 130-133.
50. Jonassen, D. H. (2008). Instructional design as design problem solving: An iterative process. Educational Technology, 21-26.
51. Wolf, E., Fiedler, M. L., Döllinger, N., Wienrich, C., and Latoschik, M. E. (2022a). "Exploring presence, avatar embodiment, and body perception with a holographic augmented reality mirror," in 2022 IEEE Conference on Virtual Reality and 3D User Interfaces (New York, NY: IEEE), 350–359. doi:10.1109/VR51125.2022.00054