User Experience and usability of a new virtual reality set-up to treat eating disorders: a pilot study

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Abstract

Virtual Reality (VR) has progressively emerged as an effective tool for wellbeing and health in clinical populations. VR effectiveness has been tested before in Anorexia Nervosa (AN) with full-body illusion. It consists in the embodiment of patients with AN into a different virtual body to modify their long-term memory of the body as a crucial factor for the onset and maintenance of this disorder. We extended this protocol using the autobiographical recall emotion-induction technique, in which patients recall an emotional episode of their life related to their body. In this pilot study, we aimed to test the usability and User Experience (UX) of this VR-based protocol. Five Italian women with AN were embodied in a virtual body resembling their perceived body size from an ego- and an allocentric perspective while remembering episodes of their life related to their body. High levels of embodiment were reported while embodied in a virtual body resembling their real perceived body size for ownership ($p<0.0001$), agency ($p=0.04$), and self-location ($p=0.023$). Negative affective state increase after session 2 ($p=0.012$), and positive affective state increase after session 4 ($p=0.006$) (PANAS). However, further iteration of the VR system is needed to improve user experience and usability of the system.

Keywords: virtual reality, embodiment, usability, user experience, anorexia nervosa.

1 Introduction

Virtual reality (VR) can be defined as a computer-generated reality in which presence is a key factor to perceive the generated virtual environment as real (Riva et al., 2019). The sense of presence is the feeling of being physically immersed in a computer-generated environment and perceiving of being able to interact with the events happening in that virtual environment that can modulate users' affective responses (Riva et al., 2007; Slater, 2009). Due to the lowering cost of VR equipment and the validated effectiveness of VR in modulating users' physical and emotional responses, VR systems are increasingly being used for promoting well-being in different clinical populations (Montana et al., 2020; Parsons, 2015).

Particularly, today there is an increasing interest in the use of VR to modulate the mental body representation of healthy and clinical populations by means of body-illusions, that is the illusion of perceiving a fake body as if this was the real one (Matamala-Gomez et al., 2018, 2020b; Serino et al., 2019). For instance, body illusions have been targeted towards specific body parts, such as in the case of the rubber hand illusion (RHI) (Botvinick and Cohen, 1998). In the RHI study participants experienced ownership illusion over a fake body part -a rubber hand- while the experimenter synchronously stimulated both the real (outside their field of view), and rubber hand (inside their field of view) by using tactile stimulation (visuo-tactile stimulus). Thus, by using synchronous visuo-tactile stimulation it is also possible to induce ownership over a fake limb, and even over an entire full body, creating a full body illusion (FBI) (Maselli and Slater, 2013). Furthermore, in VR, agency (the feel of controlling the virtual body movements) over the virtual body can be also induced by giving a synchronous visuomotor feedback to the users, feeling agency over the actions of the virtual body into the immersed virtual environment (Sanchez-Vives et al., 2010).

In addition to body ownership illusions, the body-swap illusion has been also investigated by using entire fake bodies (a mannequin) through the use of synchronous visuo-tactile stimulations to the real and fake bodies (Petkova and Ehrsson, 2008). In the study by Petkova and Ehrsson, participants had the perceptual illusion of being localized in another persons' body, or an artificial humanoid body that was physically placed in front of them as belonging to themselves inducing a "body-swap" illusion. Thus, in order to induce such body-swap illusion, (meaning the change of the participants center of awareness from an egocentric (own body) to a allocentric (another body)) the authors described the following criteria which must be occurring at the same time: a) the use of a synchronous visual and somatosensory feedback about the state of the body, b) the use of a fake body with enough human

features, and c) the adoption/use of a first-person perspective of the fake body. In this concern, other investigations have shown that it is possible to modify the body image in patients with AN over an entire virtual body to decrease body-size overestimation (Keizer et al., 2016). Through the of virtual bodies it is possible to measure the conscious internal representation of one's body appearance allowing participants to compare the represented virtual body to their ideal body appearance and to their real body appearance (Neyret et al., 2020). Moreover, Serino and colleagues (2019) used the body-swap illusion in patients with AN, to evaluate possible changes in their distorted body representations. These results are coherent with many studies that demonstrate the power of VR-based body illusions and embodiment in another body to change behavioral and physiological responses (Riva et al., 2019; Slater and Sanchez-Vives, 2016).

However, although the use of body illusions through VR systems is growing in clinical applications, few studies aimed to investigate the usability and user experience while using VR systems for clinical purposes. To this aim, in the present study we investigate the usability and user experience of a VR-based system directed to modify the mental body representation of patients with AN through a full virtual body illusion and body-swapping in VR.

2 Background. State of art

2.1 Virtual reality for positive change

Today, the use of technology for human-computer interaction to improve users' quality of life has been growing (Riva et al., 2012). One of the most important aims in the use of technology in clinical applications is the increase of happiness and psychological well-being (Gaggioli et al., 2016). In this regard, the recently emerged field of positive psychology that refers to the bio-psycho-social aspects of cognitions, emotions, and positive experiences (Burgess, 2019; Seligman and Csikszentmihalyi, 2000), has been paving the way to the development of new technology systems directed to improve the quality of personal experience, leading to the enhancement of well-being of the users (Botella et al., 2012). Particularly, the positive psychology approach aims to develop new interactive systems that 1) enhance positive emotional states through "hedonic technologies", 2) facilitate engagement and sense of flow through the use of "eudaimonic technologies", and 3) promote social interaction and connectedness with society by using "interpersonal technologies" (Gaggioli et al., 2016). In this regard, Riva and colleagues (Riva et al., 2012) introduced the concept of 'Positive Technologies' directed to

the scientific use of technology to improve users' personal experience, based on positive psychology. More specifically, the authors described three different ways to positively manipulate the users' experiences using technology: i. by structuring personal experience through rules, specific goal interventions, and giving a feedback; ii. by augmenting personal experience through the use of multisensory and multimodal systems; and iii. by replacing personal experience with a fake one (e.g a virtual body). Moreover, the use of such technology for positive psychological interventions must accomplish the following: emotional quality (affect/emotional regulation), engagement and actualization (presence and flow), and connectedness (socialization and networking flow) (Triberti et al., 2016). Thus, rather than positive technologies we should call them transformative technologies for supporting clinical and personal change (Riva et al., 2016).

Transformative technologies have been used for affective/emotional regulation (Roth et al., 2019), flow and engagement (Gaggioli et al., 2016; Matamala-Gomez et al., 2020a) psycho-social well-being (Botella et al., 2012), brain training and empowerment (Cipresso et al., 2014), stress and anxiety management (Grassi et al., 2011), and for becoming another through body swapping (Serino et al., 2016, 2019). One of the main human-computer interaction systems for transformative experiences to enhance psychological well-being is virtual reality (Riva et al., 2016). VR is an advanced form of human-computer interface that enables participants to interact with an immersive virtual environment which has naturalistic characteristics that the experimenter may manipulate for neuroscientific research or clinical applications (Riva et al., 2016; Spanlang et al., 2014). Through VR systems we can induce the feeling of being embodied in another body (Kiltner et al., 2012a), and modify the morphological characteristic of a virtual body (Kiltner et al., 2012b; Matamala-Gomez et al., 2020b). Following this line, full virtual body illusions through VR has been used to improve body representation in clinical populations with eating disorder patients, specifically in patients with AN (Corno et al., 2018; Keizer et al., 2016; Mölbert et al., 2018; Serino et al., 2019).

2.2 The problem of anorexia

Diagnostic and Statistical Manual of Mental disorders-5 (DSM-5) describes Anorexia Nervosa (AN) as a psychiatric disorder characterized by significant low body weight and the consequent fear of gaining weight (American Psychiatric Association, 2013). A diagnostic criterion for AN is a distortion in perceived body shape and weight, that is a distortion in the patients' body image (American Psychiatric Association, 2013). In this regard, in the last 20 years several studies investigated this disturbance in body perception in patients with AN. One example is the study conducted by Smeets

(1999) in which the author observed that patients with AN considered a thin, normal, overweight or an obese body thinner than what healthy control group considered (Smeets, 1999). However, Tovee and colleagues observed that besides to the reported overestimation body size of the body, AN patients had the tendency to consider lower body mass more attractive than a normal one (Tovee et al., 2000). Further, in this study they also observed that the less the body mass index, the more the overestimation of the body size. Moreover, healthy controls and patients with AN differ for the amount of attention directed to specific parts of the body. One example is the study conducted by Freeman and co-authors (1991) in which healthy controls focused their attention on four areas of the body (face, chest, abdomen, and legs), while patients with AN spent more time observing their legs and abdomen than observing their face (Freeman et al., 1991).

From a neurobiological point of view, alterations in the parietal cortices have been linked with spatial and body representations and body ownership (Serino et al., 2015), and with the processing of multisensory integration related to body perception (Riva et al., 2015). Specifically, alterations in the posterior parietal cortex are related to visuospatial processing (Serino et al., 2015). Altogether, these neurological alterations block the online (how our body is right now)-offline (how our body is normally like) interactions to create a coherent representation of our body by the integration of the different sensory signals arriving to our body (Riva, 2014). Hence, according to the latest studies, the integration of new technological systems providing multisensory information such as virtual reality systems can provide new treatment strategies to deal with body image distortions (BID) in patients with AN.

2.3 Virtual reality and anorexia

VR is a useful technology to deal with BID (Döllinger et al., 2019; Riva et al., 2014). In this regard, several studies investigated how to apply VR for both assessment and treatment of the BID in patients with AN (Dakanalis et al., 2017). One of the first studies aimed to investigate the effects of VR in the treatment of eating disorders was conducted by Riva and colleagues (2000), who described the first results of an experimental cognitive therapy in a virtual reality generated environment in two subjects suffering from eating disorders, showing an improved body awareness after the VR exposure. Further, other studies have shown that the combination of a cognitive behavioral therapy with a VR training improves not only the BID, but the eating psychopathology (Perpiñá et al., 2003). The continual improvement of virtual reality systems has led to more sophisticated interventions to treat BID in eating disorders. In addition to the use of VR for the modulation of BID, it has been show that it is possible to change the altered experience of body size in patients with AN can be changed by inducing a full

body ownership illusion of a virtual body, even for highly emotional body parts (e.g. hips, abdomen) (Keizer et al., 2016). Moreover, VR can be also used to assess self-construction processes in patients with AN. In relation to this, a well-validated VR intervention was used to study the presence of deficits in the egocentric, and allocentric referring frames processing in 12 patients with AN compared with 12 healthy controls (Cipolletta et al., 2017). Moreover, this study reported significant impairments in spatial abilities, unidimensional constructing, and an exaggerated construction of the self as perceived by their selves and others while assessing AN in a VR environment [38]. Virtual reality has been also used to generate realistic virtual bodies, through a three-dimensional body scan, to assess BID in AN (Mölbart et al., 2018). Interestingly, Mölbart and colleagues observed that BID in AN may be driven by a mental distorted representation toward the desired body, instead of an overestimation of their actual body weight. Finally, Serino and co-authors used FBI in an immersive VR environment within a three-session VR body-swapping training protocol in one patient with AN to effectively monitor changes of multisensory information perception in body integration, and to test the use of such VR protocol as a driver to promote body representation changes in patients with AN (Serino et al., 2019). In this last study, a reduction in BID and an improvement in the estimation of the patient body size were observed after three session of a body-swapping VR protocol (Serino et al., 2019).

2.4 Virtual reality, usability and user experience

Traditionally, studies on VR environments have focused on the ability that this kind of environments have to influence peoples' perception (Riva et al., 2019), emotions (Botella et al., 2007), motivations and actions (Slater and Sanchez-Vives, 2016): elements like these make up the criteria for effectiveness of the system, that is if the users can reach their aim with an adequate level of accuracy and completeness within the system¹. More recently, another criterion of appropriateness emerged: User Experience (UX). UX is considered to be a multi-dimensional construct (Hinderks et al., 2019) that includes "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". Perceptions and responses are a general term indicating that perceptions, emotions, cognitions, motivations, expectations, and actions, all play a role in determining the persons' experience of a system (Winograd and Flores, 1987) before, during, and after the interaction, as indicated by the International Standard Organisation¹. ¹<https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-1:v1:en>

Usability is one of the cornerstones of UX and includes the optimization of the user interface and the perception of ease-of-use and learnability (Nielsen, 1993). In this perspective, elements such as breakdowns and focus shifts (Steed et al., 2003) are considered usability criteria: they indicate a

misalignment between the users' actions and the system, which causes the technology to become non-transparent and the user to engage in higher cognitive processes to identify the error (Steed et al., 2003). While usability aspects are important, and are necessary for designing an optimal user experience, they are not sufficient to guarantee a good user experience: if UX is to be considered in a holistic perspective (Pallot and Pawar, 2012), it has to take into consideration the previously mentioned psychological facets of the users, usability and effectiveness of the system.

The present pilot study aims to test the effectiveness of a body-swapping VR-based system in terms of affective responses and embodiment scores, and to evaluate its usability and user experience using a quality-quantitative holistic UX perspective.

3 Methods

3.1 Participants

Five Italian young women diagnosed of AN following the criteria in the DSM-V participated in this study (age= $17\pm1,87$). All five patients with AN presented a BMI < 16 (BMI= $15,95\pm0,61$). Presence of neurological pathologies, history of brain or traumatic brain injury, cognitive deficits and presence of other psychiatric disorders as a comorbidity of the AN were considered as exclusion criteria. The parents of the all five participants signed a consent form to allow the patients to participate in this study. The study was approved by the local ethical committee of the Istituto Auxologico Italiano.

3.2 Study design

The VR-based protocol consisted of four VR experimental sessions of one hour each, taking place during two weeks (two VR sessions per week). Each VR experimental session consisted of two parts: in the first part the patients observed the virtual body from an egocentric (first person perspective) view, in the second part from an allocentric (third person perspective) one. This process, generated the body-swapping illusion induced through synchronous visuo-motor correlations between the real and the virtual body. The presentation of the allocentric or the egocentric perspective of the virtual body was counterbalanced among the patients and sessions. Furthermore, the body mass index (BMI) of the virtual body was changed throughout the VR sessions. In the first VR session, the BMI was the same as the real BMI of the patients with AN (<16), and then this was increased throughout the experimental session until reaching the considered normal BMI (18.5). Further, the autobiographical recall emotion-

induction technique (Chirico et al., 2018) was used: patients were asked to recall negative emotional episode of their life related to the low BMI, and a positive emotional recall related to the normal BMI.

Before and after the experimental sessions, patients underwent a baseline assessment in which attitude, cognitive, affective, and perceptive variables related with their clinical condition were tested. In order to evaluate the usability and user experience of this VR-based system, during the VR experimental session the following techniques and tests were used: The think-aloud protocol (Boren and Ramey, 2000), which consist in semi-directed and undisturbed users' verbalization while using and interacting with the VR set-up, providing useful information for interpreting and determining verbal data to identify system deficiencies; Embodiment assessment (Longo et al., 2008), during the experimental session after the exposure of each virtual body condition the level of embodiment, (the sense of body ownership, self-location, and agency toward the virtual body) was assessed by using three different questions in which patients had to indicate how much they agreed or disagreed with each statement in a 7-point Likert scale, from -3= totally disagree to +3=totally agree. The embodiment questions were the following: i) ownership: "I feel that the virtual body is my body"; ii) location: "I feel that my real body is at the same location of the virtual body"; iii) agency: "I feel that I can move freely if I want". Then, after the VR experience, we assessed the overall VR-Experience in terms of ownership, agency, and self-location, with a full 16-items VR-Experience Questionnaire seven-point Likert type from 1: 'totally disagree' to 7: 'totally agree', adapted from (Longo et al., 2008), and the user experience with the User Experience Questionnaire (UEQ-S) seven-point Liker type from -3 (horribly bad) to +3 (extremely good) for each of the 26 items of the questionnaire (Schrepp et al., 2017). User experience after the VR exposure was assessed in session 1 and session 4. In order to simplify the results obtained in the 26-item UEQ, the scales of the UEQ can be grouped into pragmatic quality (Perspicuity, Efficiency, Dependability) and hedonic quality (Stimulation, Novelty). Pragmatic quality describes task related quality aspects, hedonic quality the non-task related quality aspects. Finally, in order to assess the affective state of the patients before and after the VR-protocol we used the short-form of Postive and Negative Affect Schedule (PANAS) (Thompson, 2007). The short-form of PANAS is a 10 item scale (five positive affective items and 5 negative affective items), in which patients have to indicate on a five-point Likert scale how much they agree (5) or disagree (1) are with each statement of the test, in which the maximum score for either the positive or negative items is 25 points (the higher the score the higher the positive or negative affective state). A 4-week follow-up qualitative interview was conducted to verify the final user experience evaluation and the overall experience of the proposed protocol.

3.3 Virtual reality set-up

A head-mounted display (HMD, Oculus Rift) with a resolution of 2160x1200 pixels per eye in a PenTile OLED panel and with a refresh rate displayed at 90 Hz to show the virtual environment, which was programmed with Unity version 3.1 (Unity Technologies, San Francisco) was used. The HMD was attached to a laptop computer with an HDMI. The virtual body was taken from the (Unity Library) and configured to match the gender (female) of the participants. In order to induce FBI during the experimental session, synchronous visuomotor stimulations were used, with the virtual body reproducing the real movements of the participants simultaneously. To this aim a motion tracker device connected to the computer a Microsoft Kinect sensor xbox one (www.xbox.com/en-US/kinect) was used. Figure1 A, B.

3.4 VR session procedure

Patients with AN were asked to stand in front of the computer. During the experiment, patients wore the HMD and receive verbal instructions from the experimenter to follow the experimental session, and to generate the think-aloud and sense of embodiment toward the virtual body. Once the patients put on the HMD, the experimenter asked the patients to look down to their feet, where instead of their real body, they would observe a virtual body co-located with their real body from a first-person perspective (egocentric view) (see figure 1 C, D). Once the patients observed the virtual body and the virtual environment, the experimenter asked them to start the think-aloud while slowly moving their arms upwards, in order to experiment with their virtual body, and to visually explore the virtual environment. Finally, patients were asked to co-locate their real body aligned with the virtual one in order to encourage the embodiment. At this point, patients were asked to verbally express what they felt and their sensations. All patients' responses were audio recorded by the experimenters. Once the think-aloud was concluded VR experimental session started. Each VR experimental session was composed of four different parts: 1) Embodiment phase, 2) Virtual body perspective, 3) Modification of the BMI, and 4) Autobiographical recall. During the embodiment phase (1), embodiment toward the virtual body using synchronous visuo-motor correlations was induced (Kokkinara and Slater, 2014). The experimenters asked the patients to co-locate their real body with the virtual one and not move from that position until the end of the VR session. Then, the experimenter asked the patients to slowly move their real arms from the floor to the ceiling, and slowly repeat this task for three-four

293 times. Then the patients observed how their virtual arms moved synchronously at the same time and in
294 the same direction, inducing a sense of agency toward the virtual body movements. During the

295 embodiment phase, the BMI of the virtual body was different for each experimental session: in session
296 one and two the BMI of the virtual body was equal to the patients with AN real BMI (< 16), in
297 session three the BMI of the virtual body increased to 17.5 (closer the normal BMI), and in the
298 fourth session it increased again to 18.5 (normal and healthy BMI). In the virtual body perspective
299 phase (2), the experimenter changed the perspective view of the virtual body in an allocentric or
300 egocentric perspective depending of the session (see study design methods). After changing the virtual
301 body perspective (3), the experimenters asked the patients to verbally indicate the virtual body
302 dimension until it reached their desired body size, and then to their perceived real body size
303 for both allocentric and egocentric virtual body perspectives, and the experimenter modified the
304 avatars' BMI through the VR computer interface accordingly (visuomotor correlations were re-
305 induced after each virtual body exposure). After the observation of each virtual body condition
306 embodiment toward the virtual body was assessed. Finally (4), the patients had to associate their virtual
307 body to a negative (session 2 and 3) or positive (session 4) event of their life depending on the session
308 (see study design section). At the end of the experimental session patients had to fill in a full
309 embodiment questionnaire.

Figure 1. Virtual reality set-up and body swapping illusion. A) Participant wearing the HMD. B) Virtual reality set-up composed of a laptop, Microsoft Kinect tracking system, and Oculus sensors to track body position. C) Egocentric view perspective of the virtual body. D) Allocentric view perspective of the virtual body.

4 Data handling

All statistical tests for the repeated measures of the study (embodiment questions after each condition and data from PANAS test) were performed in Stata 13 (StataCorp LP, College Station, TX, USA). These measures are therefore a mixed-effects design, with virtual body BMI (real/desired) and Body perspective (egocentric/allocentric) as fixed-effects, and ownership, location, and agency scoring as the dependent variables, with random effects over the “individual subjects”. Differences in embodiment questions across conditions with multilevel mixed-effect ordered logistic regression test (the ‘meologit’ function in Stata) were analyzed. Furthermore, a multilevel mixed-effects linear regression test (the ‘mixed’ function in Stata) was performed to observe the effects of the VR intervention on the positive and negative affect of the patients with fixed-effect on Time (pre-VR/post-VR) and positive or negative PANAS scoring as the dependent variable. Due to the small sample size of the study ($n=5$), we show a descriptive statistical of data for the UEQ. Results from the UEQ were analyzed by using the UEQ data analysis tool (version 4) (Schrepp, 2015). Qualitative thematic analysis was used to identify recurrent themes in the interviews. The authors used interview notes and recordings to report the main patterns within the data. Recordings of the thinking aloud section of the study were generated and analyzed in a concurrent ethnography perspective, a specific sub-methodology of focused ethnography (Martinez Perez and Camas Baena, 2016) adapted for technological design and to support usability.

5 Results

5.1 Embodiment questionnaire scoring

During the VR session, we assessed the level of embodiment after the exposure to each virtual body condition (real vs. desired virtual body), from an egocentric or allocentric perspective. Further, at the end of each VR session we assessed the overall level of embodiment. Patients reported good levels of embodiment when the BMI of the virtual body to their perceived real BMI was changed. Specifically, patients reported significantly higher levels of ownership ($z=4.98$, $p<0.0001$), location ($z=-2.27$, $p=0.023$), and agency ($z=-2.05$, $p=0.041$) toward the virtual body when they were embodied in a virtual body with their perceived real BMI, than when they were embodied in a virtual body with their desired

BMI (Figure 2). However, no differences were found for ownership ($z=1.41$, $p=0.159$), location ($z=-0.56$, $p=0.577$), and agency ($z=-1.07$, $p=0.286$) while observing the virtual body from an egocentric (1PP) or allocentric point of view (3PP). Figure 2.

Figure 2. Embodiment levels increase with the perceived real BMI of the virtual body. Ownership, location and agency ratings after observing the virtual body with the real perceived BMI show higher scores compared to the observation of the virtual body with the desired BMI. Boxplots show medians (horizontal lines), interquartile ranges (IQR; boxes) data outside 1.5xIQR (whiskers) and outliers (o). * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

In order to simplify the results obtained in the 16-item embodiment questionnaire four different variables were created by grouping the items regarding to ownership questions, ownership control questions, agency questions, and location questions of the questionnaire. The outcomes obtained from the embodiment questionnaire show a reported median level of embodiment (median=3) for patients

after the whole VR experience. No significant differences were found for ownership and ownership control questions; however, ownership control variable show a higher scoring than ownership variable Figure 3.

Figure 3. Embodiment ratings after VR exposure. Questionnaire ratings after the virtual reality exposure show that patients reported median levels of ownership, ownership control, agency and location of the virtual body, ownership scores increased in the ownership control questions. Boxplots show medians (horizontal lines), interquartile ranges (IQR; boxes) data outside 1.5xIQR (whiskers) and outliers (o).

5.2 PANAS and user experience questionnaire

The reported levels of the positive and negative affective state of the patients before and after each VR session show a statistically significant difference between pre-VR and post-VR after the second VR session for the positive affective scoring after the VR exposure ($z=-2.50$, $p=0.012$). Nevertheless, patients reported significant lower negative affective levels after the four VR session compared with levels reported before the VR exposure ($z=2.74$, $p=0.006$). See figure 4.

Figure 4. Negative affective state increase after session 2 and positive affective state increase after session 4. The graph shows the positive and negative affective state ratings differences before and after the VR exposure in each session (from session 1 to session 4). Boxplots show medians (horizontal lines), interquartile ranges (IQR; boxes) data outside 1.5xIQR (whiskers) and outliers (o). * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

5.3 User experience outcomes after VR exposure

The results obtained in the UEQ showed that patients perceived the system as more attractive after the VR exposure in session 1 (mean $\pm$ SD=0,533 $\pm$ 0,462) than after session 4 (mean $\pm$ SD=0,00 $\pm$ 0,593). On the other hand, patients perceived the system more familiar and easier to use after session 4

372 (mean±SD=1,125±0,721) than after session 1 (mean±SD=0,950±0,596). Average scoring for novelty
 373 were higher after session 4 (mean±SD=1,688±0,943) than after session 1 (mean±SD=1,550±1,229),
 374 figure 5.

375 **Figure 5. User experience after VR exposure in session one and four.** (A) UEQ ratings after VR exposure in session 1,
 376 were high for attractiveness and novelty. (B) UEQ ratings after VR exposure in session 4, were high for perspicuity and
 377 novelty. The bar chart shows the media and standard deviations obtained in the six different qualities of the VR-system.

378 5.4 Thinking aloud

379 The thinking aloud technique revealed that no element in the virtual environment gained more attention
 380 than the others: two patients first focused on the virtual body and two on the virtual environment. The
 381 virtual environment is described by most patients in details, giving attention especially to the interior
 382 of the room. The virtual world outside the window is not given much consideration. The description of
 383 the virtual body is more critical. N=4 patients used personal nouns and pronouns when describing the
 384 virtual body, which indicates a good level of identification with the virtual body (“I saw myself
 385 reflected in a mirror”). When there was a break-down between the participants’ movements and the
 386 virtual bodies’ (uncontrollable movements and/or non-responsive virtual limbs) the embodiment failed,
 387 as indicated by the participants’ switch to third person noun and pronouns (“The virtual body moves

as I move but sometimes (it does) not” (patient 1), “The virtual foot is not co-located with my real foot, it seems twisted” (patient 3). Overall, patients experienced an average of two break-downs of the illusion per session. Although for some specific aspects of the virtual experience the opinion of the patients was different, patients’ reported speech during the thinking aloud phase was consistent among the patients.

5.5 Patients interview

The following results are extracted from a follow-up interview of three of the patients with AN of the study, one month after the VR experience. First, all patients had previous knowledge of VR but only one patient actually had previous experience with a VR environment used in a clinical setting. One had previously tried a VR-based entertainment system, but only in one occasion. Secondly, we observed that all three patients appreciated the contextual features of the VR room, which was deemed clear and detailed. However, the virtual body generated contrasting feelings: while the patients could tell that it was meant to be them, the virtual body was usually perceived as unfamiliar and not similar enough to their own body. This feeling may be exacerbated by the several breakdowns they experienced when the virtual body movements would not mirror their own. The body similarity between the virtual body and the real body of the patients emerged as particularly relevant especially in the two youngest interviewees, who expressed frustration in not being able to control the body of the avatar body completely, both in its physical aspects and in its limited motion. This fixation on the body is on par with the AN pathology and with another topic that emerged from the interviews, which is the scarce understanding of the goal of the proposed VR experience and the 4-VR sessions. The system itself does not give any hint of the aim of being in the VR and does not give any kind of feedback to the participants, and relies on the research personnel managing the technological set up to give instruction and sense to the experience. This contradicts Nielsen’s visibility of system status heuristic [53], which dictates that a system should always keep the user informed of what is happening through timely feedbacks. Since they do not fully understand the aim of the program, participants are also unable to express an opinion on the usefulness of the system and the entire protocol: they entered the study because they were encouraged by the medical personnel who presented it (not the researchers) to their parents. They reported that it does not seem well connected to their healing process and their activities at the hospital. The immersive VR experience is deemed ‘weird’ and ‘strange’ at the beginning of the protocol, but participants said that it is easy to get used to.

The 4-session protocol is ‘boring’ and ‘repetitive’: participants did not perceive any change in the avatars and in what they were asked to do in the environment. While this may be positive from the research point of view, it is not optimal for the continuing levels of motivations of the users, who may abandon the program or decide not to repeat it. The interviewees said they would continue/re-attend the program due to the fact that it is very innovative and they like the VR aspect of it, which is also the reason they would suggest others to try it. So, the VR systems’ novelty and innovation is the main driver for continued use. Another important emerging topic is the lack of sense making regarding the experience in the participants’ life and healing process: while one participant said the experience stimulated reflections and it may be useful talking about it during the healing process, the rest of the participants said that they did not discuss it in depth nor with their parents and friends nor with their health care providers. The emotional response they had to both the VR technology and the program in its entirety was also very limited and weak: other than the initial strangeness of VR and the tiresomeness perceived during the program, two participant out of three did not report any particular negative or positive feelings at all, even regarding the emotional recall part. Then, the experience was categorized as a one-off experience which broke the monotony of their daily life. This makes sense in the organizational context the system where was tested, which is a hospital offering Occupational Therapy-based support to patients with AN. To maximize the UX of the full program it may be useful to really include it in the therapeutic process, as experiencing another body is a transformative experience which may include changes at self-level.

6 Discussion

Immersive virtual reality can induce sense of owning a virtual body by providing synchronous visuo-motor correlations between the real and the virtual body to the users (Sanchez-Vives et al., 2010). Further, VR can generate the perceptual illusion of swapping toward another fake body (Petkova and Ehrsson, 2008). Such virtual body illusions can be used for clinical proposes to modulate body perception in patients with a body image distortion due to their clinical conditions (Matamala-Gomez et al., 2019). Although some studies investigated the use of embodiment while using VR systems in clinical applications, few studies reported how the characteristics of the user experience is while using immersive VR systems. The present manuscript shows the results obtained in a pilot study conducted with five patients with AN to explore user experience by analysing individual thinking about the system while using it. In addition, the level of embodiment and the affective modulation after the VR exposure was also assessed. Further, a personal interview with each of the patients participating in the study one

month after the use of the VR system as a follow-up of the personal experience was conducted. The present pilot study shows that the proposed VR-body swapping protocol can be used as a powerful tool in clinical population suffering from body image distortion. The VR-system was able to induce high levels of embodiment and of subcomponents of embodiment: sense of ownership, agency, and self-location, toward a virtual body while being embodied in a virtual body with a real perceived BMI. However, embodiment levels decreased when the patients were embodied in a virtual body with their desired BMI. This result is in line with the study conducted by Serino and co-authors (2019) in which the authors showed how the VR-based body swapping illusion protocol worked as a helpful and useful tool to assess and to modify body distortions in clinical populations. The patients perceived the BMI of their real body as larger than their real BMI and this can be due to the fact that patients identify more with the virtual body presenting their real perceived BMI. In this regard, the fact that patients identify more with the real perceived BMI virtual body shows the body image distortion of the patients participating in our study, as they perceived real BMI is larger than their actual real BMI. Moreover, as in the study conducted by Serino and co-authors, this study confirms that high embodiment levels indicate that body image in clinical population can be re-shaped, with body image distortion by using the here proposed VR-body swapping illusion protocol. Secondly, the proposed VR protocol together with the autobiographical recall technique seems to modulate the affective state of the patients with AN after the VR exposure. This result is not only due to the VR exposure but also to the positive or negative autobiographical recall associated to the virtual body (see VR procedures section). In fact, the negative affective state increased after the VR exposure in session two, in which patients had to associate their observed virtual body (low BMI) with a negative event of their life, and positive affective state increased after the VR exposure in session four, where patients have to associate their observed virtual body (normal BMI) with a positive event of their life. This result is very relevant from a clinical point of view as even though this affective component had been proposed to be used in patients suffering from obesity (Riva, 2011), this is the first time that an affective component was associated with the virtual body observation.

Regarding the usability and the UX of the system, both the UEQ, break down analysis, and the interviews revealed that the participants' evaluation of the experience was sub-optimal: novelty and innovation of the VR system were the positive aspects of the program; on the other hand, the usability of the system was negatively depicted due to the several break-down of the virtual body illusion because of some problems with the tracking movement system and probably also due to latency issues (Friston and Steed, 2014). The results collected from the interviews also explain the embodiment levels

obtained in the embodiment questionnaire after the VR exposure, in which we observed median levels of ownership, agency, and self-location toward the virtual body. However, the higher scoring obtained in the ownership control variable may be explained because of the clinical condition of the patients presenting a distorted body image that is also present into the virtual environment. This result reflects a limitation in defining the limits of their body, as expected and in keeping with other studies that used virtual embodiment in clinical populations presenting body image distortions (Matamala-Gomez et al., 2018; Mölbert et al., 2018; Serino et al., 2019).

7 Limitations

A limitation of the present study is the small sample size ($n=5$) which reduces the generalizability of the results obtained with the proposed VR-body swapping illusion protocol to other clinical populations. However, the obtained data in the study is homogeneous enough to hypothesize that other critical factors will not appear when using this VR system with a larger sample size. Another limitation of this study is that cyber sickness and other psychological constructs such as sense of presence after the use of the VR system were not specifically assessed. However, none of the 5 patients reported signs of cybersickness (Rebenitsch and Owen, 2016) neither in the thinking aloud phase or in the follow-up interviews about the system. Further trials should also consider introducing measures to control for latency aspects (Friston and Steed, 2014).

8 Conclusion

The present study demonstrated that the proposed VR-body swapping illusion protocol can be used for both assessment and clinical proposes in clinical populations suffering from AN. Further, the study shows the feasibility to use a low-cost head-mounted display connected to a laptop, through which patients can be immersed in a virtual environment and embodied into a virtual body. The VR system offers the possibility of changing the morphological characteristics of the virtual body (e.g. changing the BMI of the virtual body) and observe it from different perspectives (third- vs. first-person), targeting body image distortion in patients with AN through a powerful and effective tool. Further, embodiment scores show that the system works for its intended purpose of experiencing another body. While we can consider the system effectiveness in inducing embodiment, further iteration of the system and the full program should aim to introduce goal transparency both in and out of the VR system, shorter latency timing and more accurate tracking system, and avatar personalization to improve usability and user experience.

9 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

10 Author Contributions

MM-G contributed to the data collection and statistical analyses, bibliographic review, conceptualization, and writing of the manuscript. EB contributed to the data collection, writing and conceptualization of the manuscript. CM and AC contributed to the data collection, and conceptualization of the study. OR contributed to the bibliographic review and writing of the manuscript. SS and GC contributed to the conceptualization of the study and design of the virtual reality scenario. NP, AD, CC contributed to the patient collection and in the conceptualization of the clinical aspects of the study. GR, and FM contributed to the supervision of the manuscript. All the authors approved the final version of the manuscript for submission.

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