

Alleviating Symptoms of Body Integrity Dysphoria Through Augmented Reality–Based Therapeutic Intervention

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Abstract

Body Integrity Identity Disorder (BIID) is a rare and complicated disorder related to the individuals who feel a severe misconfiguration between the physical body and internal body image so that they usually desire to amputate healthy limbs. There are no currently established treatment strategies of long-term clinical response in an ethically accepted or valid manner. This paper proposes a new solution of applying augmented reality (AR) technology to stimulate the process of amputation and measure its impact on the BIID-related distress. Two men with BIID took part in a pilot experiment with an AR system named Augmented Reality Telepresence to the Ideal Self (ART-IS). The computer assisted technology allowed their alienated limbs to be virtually removed using head mounted displays and chroma key imaging. The verbal Likert scale and the physiological markers such as the rate of heart rate, respiratory sinus arrhythmia (RSA) as well as pre-ejection period were considered to evaluate the symptom reactions. Both of the patients showed a condition of temporary but significant distinction in symptoms when exposed to AR. The responses have shown to be mostly positive in the emotional front, but the physiological evidence showed engagement but not increased distress. One patient has said that she was symptom-free several days after the session. Such results allow assuming that visual simulation of the ideal body image in AR could have both therapeutic and diagnostic importance when used by people with BIID. There is a need to carry out further research on bigger samples and longer follow-up studies.

Keywords: *Body Integrity Identity Disorder (BIID), Augmented Reality Therapy, Virtual Amputation, Somatic Self-Perception, Visual Simulation, Identity Dysphoria, Psychophysiological Assessment, Neuroethical Disorders.*

1.Introduction

The disorder of Body Integrity Identity Disorder is one of the most mysterious and controversial disorders in the modern psychiatric terms because it undermines the basic concepts of the body ownership, identity shaping process and the strategies of the therapeutic interventions. This unique neuropsychological condition looks like the irrepressible and consistent urge of the amputation or paralysis of one or more of healthy limbs leaving the strong psychological discomfort by which a person can be endangered in his/her relations with his/her own existence as a corporeal being. Whereas other body dysmorphic conditions are based on the perceived flaws or imperfections, BIID is based on a complete dissociation of a particular part of the body that is different only in that it is objectively healthy and functional, leading to the assumption that the issue involves complicated processes of neurological processing in relation to the formation of psychological identity and embodied cognition, which is poorly understood even after decades of clinical observation and the study of the phenomenon(1).

The phenomenology of BIID's disorder exceeds mere body dissatisfied by integrating the sense of profound belief occurring in the minds of the affected persons, of their true personality dwelling in the changed form of the body, namely, having fewer limbs through the process of amputation. This form of expression of bodily alienation tends to occur when individuals are at a very early age of development, being likely occasioned by exposure to amputees or or mobility aided individuals casting doubt on possible critical states of development of the body schema and self-representation that may be disturbed because of the influence of exposure to the environment or the weaknesses of inner neurological processes. The fact that these desires persist throughout the life span in spite of the stigma, the medical judgment, and the apparent danger of the action, as well as the possible consequences of acts of amputation, confirm the urgency of this disorder and the dramatic consequences on mental health and living status.

Modern treatment methods of BIID are all the more piteous, and the etiology of the disease is rather complex, the number of studies on the topic is insufficient, and the interventions that may be offered as a method of treatment have certain ethical issues. The efficacy of traditional psychopharmacologic intervention has been proved minimal,

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and, generally, the traditional psychotherapeutic programs do not change the primary symptoms of alienation and incongruence of the identity that characterize the disorder. The most debatable possible intervention is elective amputation of healthy limbs, which is caused by the so-called split in medical communities over the conceptual autonomy, beneficence, and the limits to medical intervention. Such a vacuum in therapies has necessitated the demand of finding new treatment options that will have a lasting solution in treating BIID at its core symptoms, and ensuring that they are ethical without the need of an irreversible physical surgery(2).



FIGURE 1 BIID Treatment Evolution

The creation of virtual and augmented reality technologies has at last provided a possibility of therapeutic involvement in the conditions linked with the perception of the body, its ownership, and the development of identity. These immersive technologies introduce novel modalities of manipulating sensory data, inducing changes in the perception of body, and setting the environment with a controlled exposure to specific stimuli never been possible with the help of traditional interventions. Virtual reality is capable of producing entirely fictional worlds in which a person may gain the experience of an alternative embodied experience without physical danger, whereas augmented reality can locally alter the view of the real world in a real-time environment, adding or removing or changing elements of the view, or modifying visual perception selectively. Implementation of the latter technologies in the case of BIID is potentially an especially fruitful direction, since the technologies may enable individuals to safely and repeatedly receive the desired body configuration, possibly alleviating their symptoms, without the risks and irreversibility of surgical amputation.

Neurobiological studies have recently started shedding light on possible underlying mechanisms of BIID by showing brain anomalies in the regions that deal with ownership of a body, of self, and integration of sensorimotor involvements. Neuroimaging has also found changes in activation patterns within the right parietal cortex, notably in those findings important to the integration of the sensory information and retention of body schema representations. The given findings indicate that BIID could be a particular type of the body ownership disorder, caused by the impaired neural processing and is not just a psychological/behavioral phenomenon. These neurobiological outlines are key to ensuring that specific therapeutic efforts are put in place so as to ensure that the most fundamental neural tracks are relevant so as to overcome such a pitfall instead of treating surface manifestations or symptoms that are behavioral in nature(3).

The present study is an explorative study of an extreme emerging innovation in augmented reality treatment of BIID patients based on the use of new technology to generate the controlled exposure scenarios that enable patients with BIID to see and operate in the preferred body structure. By developing Augmented Reality Telepresence to the Ideal Self (ART-IS) there is the exploration of whether virtual amputation experiences can have therapeutic effect on those with lower-limb BIID. The art process or methodology is the practice of the advanced chroma key concept to selectively eradicate the visual embodiment of the alienated appendages with preserving of the real-time interaction within the immediate surroundings simulating the effect of immersion, that is very close and provides the condition that the patients would like to have with regard to body appearance.

This study intends to fill the knowledge gap related to the treatment of BIID as well as paving the way to preliminary evidence regarding the use of technology in therapy interventions that may transform the treatment model in this problematic disorder. An original idea of applying strict monitoring of physiological effects alongside subjective reporting of symptoms to fully evaluate the treatment impact is applied in the study to both short-term and possible long-lasting improvements. This study can potentially open up bigger clinical trials and introduction of virtual reality technologies into general psychiatry practice by proving the efficacy and feasibility of augmented reality interventions.

The effects of this study are not limited to treating BIID, but can be used to guide treatment of other conditions that entail body perception alterations, phantom limb phenomenon and disorders that affect identity. The effective use of the augmented reality technology to alter the body ownership experiences may set novel paradigms of treating a massive variety of neuropsychiatric disorders coupled with providing us with a better comprehension of the non-trivial relations existing between technology, embodiment, and psychological health within the modern clinical environments.

2. Methodology and Technological Framework

The specific methodological strategy used in this study was an innovative combination of both hi-tech augmented reality and real time physiological monitoring and experiment design specifically adapted to the task of investigating the Body Integrity Identity Disorder. Technological innovation was put to massive use in preparing the Augmented Reality Telepresence to the Ideal Self (ART-IS) system, integrating several high-end hardware and software functionalities that would allow to achieve a smooth and visceral experience of virtual amputation that could be accurately manipulated and methodically analysed(4). This system was built upon the Oculus Rift DK2 stereoscopic head-mounted display that offers high-resolution 3D visualization capabilities necessary to generate convincing immersive experience and the integrated Zed Mini stereoscopic camera system allowed capturing and processing in real-time with a detail and accuracy sufficiently high to support complex visual manipulation features of the patient physical world.

Making virtual amputation work technically necessitated the creation of advanced chroma key algorithms that can work in the Unity3D game engine and enable real-time selective erasure of specific body parts of the visual field and at the same time enable a smooth flow with the rest of the background. This methodology required much attention to be paid to the lighting, the consistency of the background, and the appearance of materials to provide consistent and believable visual effects that would not disrupt immersion or cause visual artifacts that may distract from the therapeutic experience. The individual patients were set in front of professional lighted green screen backdrop, and their desired to-be-edited limbs wore special designed green socks allowing solid color coverage and allowing edge definitions to be cleaned up in a green screen surrounding. The real-time processing nature of the system permitted when patients received visual feedback of their movements and interactions with the environment in real time, thus realizing their desired body configuration, which implant the embodied presence in a very strong manner that is not possible in regular therapeutic methods.

Physiological measurement was a significant aspect of the study methodology, the analysis of which objectively reflected the reaction of the autonomic nervous system as part of the set of methods of summarizing the current state of knowledge about the subjective, that is, the reaction of a person to therapeutic effects. The research study adopted the use of a complex physiological recording system known as the Vrije Universiteit Ambulatory Monitoring System, which records electrocardiographic and impedance cardiograms in conjunction, high temporal resolution and with a clinical level of accuracy. This allowed constant recording of data pertaining to heart rate variability, respiratory sinus arrhythmia and pre-ejection period recordings and posts sympathetic activity and para sympathetic nervous system activity during the experimental session. These specific physiological markers of choice were determined by the large body of literature that showed these markers to be sensitive to psychological stressors, emotional arousal, and autonomic nervous system activation patterns during anxiety, distress and effects of therapeutic intervention(5).

The research design was an experimental within-subject repeated measures study that would interpolate each participant, therefore, the study would assume the role of an individual control and reduce individual variability that would otherwise confound or misinterpolate the results on the treatment effects. The experiment was very carefully counterbalanced in that there were two main experimental conditions: augmented reality activation (a condition defining that AR was activated, or AR on) and regular visualization (a condition that defined the absence

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of AR, or AR off), and to minimise the possible carryover effects, there was at least a thirty-minute washout interpolated between the conditions so that the physiological measures could be reverted back to the baseline levels. Within all experimental sessions, the targeted participants were subjected to systematic electrical stimulation of four different anatomical areas which are above and below the knee of the left and right lower extremities, and all experimental parameterizations of these types of stimulation were tailored to modulate BIID symptoms variables such that each subject could reliably experience lower levels of discomfort as a means to promote BIID-related symptoms, yet not enough to elicit distress or to potentially cause harm (6).

TABLE 1 Methodological Overview Table

Component	Details
Technological Framework	Augmented Reality Telepresence to the Ideal Self (ART-IS) System
Hardware	- Oculus Rift DK2 for immersive 3D experience - Zed Mini stereoscopic camera for real-time visual processing
Software Integration	- Unity3D game engine - Custom chroma key algorithms for limb erasure
Visual Manipulation Setup	- Green screen backdrop - Green socks on limbs for chroma key accuracy - Professional lighting for consistent visuals
Real-Time Feedback	- Immediate visual feedback enabled strong embodied presence - Manipulation of body image based on patient's ideal self
Physiological Monitoring	- Vrije Universiteit Ambulatory Monitoring System (VU-AMS) - Measures: ECG, impedance cardiogram, HRV, RSA, PEP - Objective autonomic nervous system assessment
Experimental Design	- Within-subject repeated measures - Participant serves as own control to reduce variability
Conditions Tested	- AR On (active condition) - AR Off (control condition) - Counterbalanced with 30-minute washout period
Stimulation Protocol	- Electrical stimuli to four leg sites (above/below knee, both legs) - Precision-controlled scalar currents - 6 stimuli per block; 20-second intervals
Pain Calibration	- Individually adjusted from barely perceptible to moderate pain - Avoided distress but ensured symptom activation
Subjective Measures	- Custom Verbal Likert Scales assessing: • BIID symptom severity • Tension • Pain • Fear • Anger

The condition was of electrical stimuli, which incorporated current delivery mechanisms of precision scalar currents, programmable intensities, duration control, and timing system to deliver consistent and reproducible stimuli presentation across the experiment sessions and the experimental participants. Stimulation intensities were identified separately by systematically testing the thresholds actual procedure which started with minimal perceptible, and then increased progressively in intensity until the participant felt moderate painfulness that were subjectively significant but within tolerable levels. Six individual stimuli were presented at each experimental block followed by a twenty-second inter-stimulus interval to ensure that the adequate time was available both to the development and the recovery of physiological responses to each stimulation and to provide adequate temporal resolution to analyze these processes further.

The subjective estimations of symptoms were performed on the basis of implementing the individual-created Verbal Likert Scales that were specifically used to define the multidimensionality of BIID-associated distress and treatment response. These scales were used to measure five different areas of subjective experience, namely, level of tension, stated the level of symptoms of BIID, physical pain, fear reaction, and anger reaction and each of the areas ended with 5-point scales rating the level of the minimum to extreme of intensity. These assessment tools had to be developed paying close attention to the phenomenological peculiarities of BIID experiences since no validated instruments of assessing responses to virtual amputation interventions were available in non-amputated populations. The scales were repeated over time on several occasions during each of the experimental sessions

giving precise temporal resolution of alarm switching and response to treatment that could be compared with correlation with other simultaneous measures.

The processes of establishing baseline consisted in presenting neutral visual stimuli which were chosen out of the validated image databases of emotions and explicitly selected to have no body-related content or any other emotionally evoking factor that could affect later results of the experiment. It was during these baseline periods that the specification of individual physiological and subjective response patterns could be done which could be used as parameter of evaluating manipulation induced treatment effects(7). The experiment was characterised by the keenness in the experimental controls, standardization of procedures and extensive measurement methods which were key determinants in coming up with qualified and understandable research findings that could be adjudged to play a significant role in the myriad research literature which is substantiating BIID treatment interventions, and enhance our horizon on this complex and challenging clinical condition.

3.Patient Demographics and Clinical Presentations

The sample group of this inquiry comprised two adult men who were participants of a niche patient support group associated with the Amsterdam Universitair Medische Centra, who provided highly considered illustrations of the main phenomena of Body Integrity Identity Disorder and also met extreme standards of inclusion limits that would serve to establish research validity and participant safety. Both of them were given a formal BIID diagnosis by qualified psychiatrists who are specializing in body image disorder and they conducted the BIID diagnosis based on accepted clinical criteria that focused on the existence of ongoing wishes to have their limbs removed based on the desire of affirming their identity completion rather than sexual satisfaction, pain alleviation or psychotic thoughts. The recruitment was extensive with screening processes to ensure that no participant had comorbid psychiatric diagnosis that could invalidate the assessment of the treatment response, substance use issues that would distort the accuracy of the physiological monitoring, or serious medical issues that could be dangerous during the therapy participation.

Patient One had a very strong clinical history which includes the development of desire to get amputated at the early childhood age when she underwent a formative experience involving another child with a below-knee amputation and a good deal of movement by means of a wheelchair. This early experience seems to have motivated the construction of a series of enduring fantasies and desires about attaining a similarly shaped physical body and the patient indicated that her experience of seeing the amputee child caused her to experience a sudden and profound feeling of recognition and desire, which remained with her even throughout later development. The patient in question wanted a single amputation below knee of his right lower extremity with highly specialized anatomical preferences as to the exact site and length of the right lower extremity that he wanted amputated. In the patient, the corpus wanted to cause acute distress within the psychological sphere, being associated with the impossibility of attaining the desired body structure and presenting itself in the form of constant feelings of incompleteness, social isolation, depressive symptomology, which affected academic achievements, social interactions, and the overall quality of life to a large scale(8).

The behavioral changes that Patient One developed indicated advanced stratagem that was aimed at approximating his desired body structure and performing activities in the light of the practical constraints of his intact anatomy. The main tool he used to cope with the disability was imagining himself in wheelchair using elaborate simulations and tightening his right leg in a particular manner to present the visual effect of a below-knee amputation enabling him to live short sessions of what he wished to be close to reality. These simulating sessions went on to within an hour, because they would become uncomfortable as a result of the onset of paresthesias, and circulation-related symptoms in the bound limb, that would require frequent interruptions before he could get a sustained sense of his ideal body structure. The patient said that such simulation activities gave temporary respite of BIID-related distress and gave the patient some sense of completeness and authenticity that was otherwise lacking in his daily life.

Patient Two also showed a similar pattern in that the wishes for amputation started early in her childhood after watching a friend of the family who had a unilateral lower extremity amputation. Nevertheless, the amputation pattern he wanted was more radical and it consisted of bilateral above-knee amputation followed by total loss of both lower limbs. Early behavioral responses observed in the patient involved spontaneous limb binding activities indicating that the patient performed these activities without any realization of how they relate to his new identity issues or the fact that there are other people who might be going through the same ordeal. The introduction of the internet connection in his adolescence stage was critical in psychological development since the online

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communities were his first experience with other people who shared the same desires and helped him for that matter, to analyze his experience through a larger lens of identity-related issues rather than D. summarizing that online experience as an isolated instance of pathology.

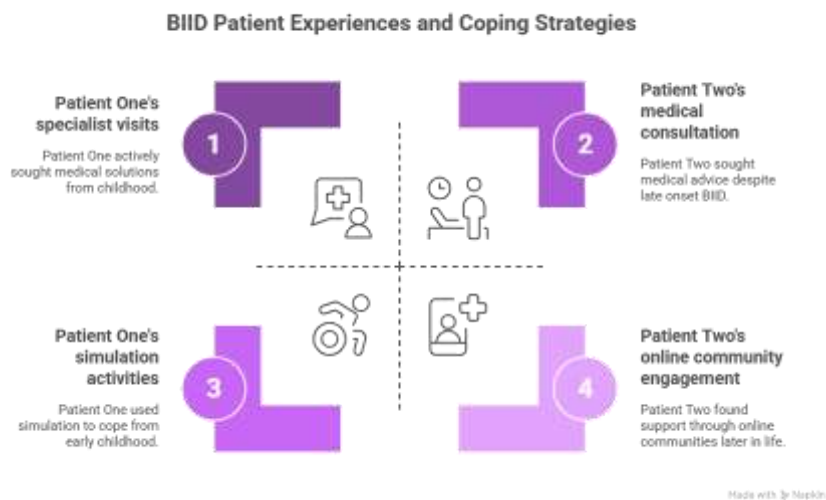


FIGURE 2 BIID Patient Experiences and Coping Strategies

The clinical images of the two patients displayed various typical features of persons with BIID who may have their amputation desires develop early in their childhood developmental stages, experience no pain, or medical issues in the limbs to be cut and remain persistent irrespective of the social condemnation and awareness of risks. Both patients did not show any signs of psychotic registration, false judgments, or thinking disorders that could explain their desires to have legs amputated using other accounting schemes. Their motives were always the same as to feel fulfilled and authentic and not to be sexually gratifying or attention-seeking behavior or a drive to procure disability claims, unlike the presentation of malingering or factitious disorder.

Prior to the present study, both patients have considered several options concerning dealing with the symptoms of their BIID such as Patient One who has seen several specialists in a medical field, like physiatrist, orthopedic surgeons, and even amputation experts, in the hope of getting a surgical operation of his case. He also had experienced unsuccessful sessions of hypnotherapy which did not give a significant relief on the symptoms and an ability to change his true wishes regarding amputations. Patient Two had embraced a more self-sufficient model of symptom treatment, trying to accommodate his BIID identity into his everyday life and avoiding seeking official medical help, but notifying his primary care doctor who has met him with supportive counseling without any form of BIID-targeted treatment(9).

The fact that each of the two patients did not have any family history of BIID or other disorders of body image supported the probability that their conditions were idiopathic in nature instead of family-specific or inheritable. Their readiness to get involved in experimental studies was predicated not only on their wish to get effective treatment but also on their desire to make the contribution to scientific cognition of their problem even at the risk of trying some new treatments. Their responses to the augmented reality intervention and the interpretation of those responses as well as the assessment of the applicability of this therapeutic intervention to other persons with a similar condition were impossible without the meticulous recording of their clinical presentations, progression of their symptoms, and their past experience with treatment, to allow obtaining essential baseline information.

4.Experimental Results and Physiological Response Analysis

The overall conclusions on experimental results identified interesting and complicated patterns of physiological involvement and subjective reactions that did not only subject the potential therapeutic management of the augmented reality intervention on the question of Body Integrity Identity Disorder but also demonstrated a complicated connection amid visual perception of the body and autonomic nervous system work-up and psychological symptoms appearance. The data of the physiological monitoring showed clear and quantitative discrepancies within the conditions of activation of augmented reality and deactivation of augmented reality, and within both participants, unique changes in cardiovascular parameters that were indicative of significant autonomic nervous system activation when experiencing virtual amputation conditions. These are physiological alterations

that accompanied self-reported experiences of symptom alteration resulting in a multi-dimensional view of treatment response, which included both objectively measurable biological changes and the subjective changes in experience that patients themselves judged to be clinically significant.

The pattern of physiological responses exhibited by the patient one when undergoing the augmented reality activation indicated a consistent reduced heart rate recording in respect to the baseline heart rate and augmented reality deactivated condition indicative of a possible relaxation response or activation of the parasympathetic nervous system unlike common responses involving stress when a patient undergoes any anxiety-inducing clinical interventions. At the same time, the lowering of heart rate was accompanied by prominent rises in pre-ejection period values and falls in respiratory sinus arrhythmia which evidenced the large-scale relationships between generous activation of the autonomic nervous system and far more intricate decreases than mere relaxation responses. We have seen that the apparent paradox of lowering heart rate with the indices of sympathetic nervous system activation indicates that the phenomenon associated with augmented reality experience might have lodged distinct physiological response traits that are fundamentally different as compared to traditional stress or relaxation responses and may well be reflecting the sheer novelty of the effect experienced when one embodies themselves virtually and the impact on their autonomic regulatory systems(10).

These physiological measures led to very important contextual information behind interpreting the rate of change, per se, because Patient One reported subjectively that there was so much stratum involvement when the system was activated as opposed to when it was deactivated with regard to how different it felt; that is, he completed the verbal Likert scale answers indicating a much more cross-modal collaboration when the augmented reality regime was in effect as opposed to the deactivation mode. Most importantly, reporting on symptom disturbance with BIID towards the end of the augmented reality sequences, he endorsed scores that, at first glance, could give the impression of a worsening of symptoms but spontaneously he explained that his response referred, in fact, not to an aggravation but to a gain in symptoms. He specified that the augmented reality experience had an influence on his BIID symptoms in a positive and welcoming fashion, considerably distinct in nature compared to the way his symptoms are normally experienced, which means that the virtual amputation gave him the chance to interact with the desired body configuration in a way that gave validation and relief, but not distress. This qualitative difference played a key role in determining clinical relevance of the intervention because it was shown that the changes in intensity levels of the symptoms did not always put forward a correlation of the symptom distress in the traditional way in which the traditional therapeutical intervention would expect.

Patient Two demonstrated a stronger and different pattern of the physiological reaction in the amount of increased heart rate activation during augmented reality activation, which could be a reaction of the sympathetic nervous system and could be connected with stress or arousal reactions. Nonetheless, as was the case with Patient One, he exhibited concomitant increases in pre-ejection period and decreases in respiratory sinus arrhythmia that reflected multifaceted interactions-of-the-autonomic-systems as opposed to mere stress effects. His subjective reports supplied instrumental background regarding the understanding of these physiological activities since he detailed how he experienced high tension levels at baseline exposure to augmented reality due to what he termed as emotionally overwhelming but explicitly positive in the sense. His literal comment that it was an emotionally overwhelming experience to see himself in this way indicated that the physiological arousal was more related to emotions active during the experience of the virtual amputation than it was to that of distress or anxiety responses. The rating scores on tension levels provided by Patient Two illustrated a distinct temporal adaptation pattern, with the peak values at the beginning of the augmented reality scenes, followed by the reduction of these scores over time, which indicated that possible psychological adaptation or rather habituation effect may have occurred due to repeated exposure to the virtual amputation experience. This habit of sudden responsiveness with gradual accommodation was similar to other studies involving exposure and desensitization therapy of anxiety disorders, which suggests that a series of augmented reality simulations may be used to deliver sequential therapeutic outcomes. Spontaneous requests by both patients to repeat the experience (of the augmented reality intervention) in the future indicated that both patients did not view the experience as negative but instead saw it as a positive experience, even though there were somewhat arousal patterns as recorded according to physiological parameters that could be considered being under stress.

Observations during the follow-up period of months may have presented the most compelling evidence of therapeutic potential, with Patient One reporting prolonged symptom improvements extending over several days after the experimental session, in messages that were free of prompting and that indicated in more detail the

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possibility of real clinical benefit as opposed to short-term experimental effects. This carry-over effect appeared to suggest that the augmented reality experience resulted in long lasting effect in the perceived symptoms or body image processing effects that did not only last through the concluding experimental situation but also remained very much in evidence long after. Ad hoc character of this follow up communication lent credibility to such reports because they were not in response to any encouragement or scripted evaluation measures that could have prompted social demands or other considerations of desirability.

The convergent evidence of physiological measures and subjective data indicated that augmented reality intervention engaged complex psychophysiological mechanisms that were quite unlike traditional theses of treatment and may have involved novel forms of bodies ownership, validation of identity, and embodied cognition that had previously not been available through traditional psychiatric therapy. Such seeming lack of correlation between patterns of physiological arousal and levels of subjective distress was substantially in conflict with traditional beliefs about mechanisms between autonomic activation and psychological well-being, and it raised the possibility that special neuropsychological mechanisms might have been involved in the virtual amputation experience, possibly to be inferred through more advanced neuroimaging and psychophysiological measurement method in future research project.

5. Conclusion and Future work

This groundbreaking study is the first systematic study of augmented reality technology as a therapeutic tool to treat Body Integrity Identity Disorder to provide preliminary data based on the viability, safety, and probable success of virtual amputation experiences to treat one of the most complex and questionable disorders in psychiatry. The consistent evidence of physiological tracking and the subjective symptom ratings indicates that well-constructed augmented reality applications may lead to quantifiable and clinically significant alterations in BIID-related symptom behavior, which is encouraging for people with a long history of having little treatment options available to them combined with being met by high levels of medical denial to the reality of their experiences. The specific results of the experiment that take the form of a coupled physiological reaction during the virtual amputation experiences, consisting of intricate interactions between the autonomic nervous system that were not observed during the average stress response or relaxation response also implies that augmented reality technology can potentially affect different neurobiological processes connected to the body ownership, embodied cognition and identity processing that should be further explored using more advanced neuroimaging and psychophysiological methods.

The potential of the therapeutic effects shown in this paper can far surpass the immediate symptom alleviation, at least as demonstrated by sustained effects reported on one participant lasting several days after a single experimental session, which may be due to initiating enduring neuroplastic changes or psychological adaptations that potentially build up over multiple administration of the virtual amputations experiences in the course of repeated therapeutic exposures. This observation is especially clinically relevant in the context of chronic and resistant to treatment of BIID, which in the past responded hardly to traditional psychopharmacological or even psychotherapeutic therapeutic measures. The therapeutic acceptability levels demonstrated by a high enthusiasm on the patients to resume the involvement of the intervention, as well as the desires to restore their uses of augmented reality in the future are very high and capable of supporting long-term therapeutic involvement and adherence to the intervention when applied in real-life clinical practice.

The methodological novelties created in the course of this study and the system of Augmented Reality Telepresence to the Ideal Self (ART-IS) in particular define a technology framework that can potentially be used to treat many types of BIID and other impairments in body perception (differing in their symptoms affecting different body parts), phantom limb syndrome, and conflicts with identity. The augmented reality approach is built in a modular fashion that will enable a precise tailoring of virtual experiences to fit refined presentations of the individual patients and preferred configuration of the bodies in way that the interventional approach hitherto has not been able to do. The potential of incorporating the augmented reality systems in therapeutic use and exploring a possible home-based treatment option where patients could maintain relief of the symptoms when not under the care of medical personnel as well as combating the limitations during the future research should aim at the optimization of the exposure parameters, dose-response relationships, and the possible applicative potential implementation of the portable augmented reality systems in the treatment of the patients.

The ethical consequences of such study are vast, since, upon successful development of augmented reality therapies, the alternatives to controversial surgical operations of amputation will be offered, resecting the rights of patients and treating real suffering of BIID cases. Such treatment intervention, which is reversible, safe, and has a potential of being effective, augmented reality interventions have the potential to cover the controversial gap between health care experts who deem elective amputation as a practice which is detrimental to patients and BIID sufferers who are in dire need of relief. This technological solution recognizes the existence of suffering in the patient and does not imply having irreparable physical intercessions, and new ethical standards may be formed to treat the conditions that violate standard medical paradigms.

The overall implications in terms of the emergence of virtual reality software in psychiatric care are also as precious since the current study evidences the fact that the immersive technology can also be employed to treat the illnesses of altered perception in self and disassociation with body image and related problems that occur in various patient groups. The positive change in body ownership experiences by using the augmented reality technology may form the basis of therapeutic practices of eating disorders, gender dysphoria, phantom limb, and other disorders where there may be therapeutic advantage of the adoption of virtual embodiment intervention. Moreover, the advanced physiological measurement methods created as a part of this study may help us to gain further insights into neurobiology of the causes of the virtual reality effect in a variety of psychiatric conditions. Among future research priorities should be large-scale randomized controlled trials to convincingly demonstrate its efficacy, longitudinal studies, and neuroimaging studies to determine how augmented reality leads to an augmented therapeutic effect on the brain. Laying out some universal assessment tools with a specific formulation on measuring reaction to virtual amputation would enable the comparison of the results to be made among research studies and enable the process of regulatory approval of clinical use to be made. Furthermore, combination therapy involving the use of augmented reality interventions with other psychotherapies should be explored in order to best achieve therapeutic gain in view of the multifactorial psychological and social burden that BIID presents.

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Conflicts of interest

The authors have no conflicts of interest to declare

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