

Brain Morphology and Limb Detachment Perception: Revealing Neural Signatures in Body Integrity Identity Disturbance

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Abstract

Body Integrity Identity Disorder (BIID) is a rare neurological condition characterized by an intense and persistent desire to become physically disabled typically through amputation or paralysation stemming from a mismatch between one's internal body image and actual physical form. While this disorder is suspected to have congenital origins, concrete neuroanatomical evidence has been limited. In this study, high-resolution T1-weighted structural magnetic resonance imaging (MRI) scans were obtained from eight individuals diagnosed with BIID and 24 matched healthy controls using a 3 Tesla MRI scanner. The brain images were analyzed using voxel-based morphometry (VBM) to detect structural differences in grey matter volume. Compared to healthy controls, individuals with BIID exhibited significantly reduced grey matter volume in the left dorsal and ventral premotor cortices, as well as increased grey matter volume in the left cerebellar lobule VIIa. These structural brain differences suggest that BIID may involve dysfunctional integration of multisensory inputs critical to body ownership perception. The anomalies observed in the premotor cortex and cerebellum regions essential for sensory-motor integration and the sense of self—support a neurobiological basis for BIID and strengthen the argument to view it as a legitimate neurological disorder rather than solely a psychological condition.

Keywords: *Body Integrity Identity Disorder (BIID), Premotor Cortex, Cerebellum, Grey Matter Volume, Voxel-Based Morphometry (VBM), Multisensory Integration, Body Ownership, Neurological Disorder, Structural Brain Differences, MRI Imaging.*

1. Introduction

Body Integrity Identity Disorder is one of the most problematical and confusing disorders in neuroscience and modern psychiatry. This is a unique neurological disorder in which a person feels compelled by an irresistible desire (and/or need) to have the healthy limb or organ of his body crippled or amputated, where there is considerable discrepancy between his or her self-perceived body image and his or her real physical image. Contrary to other types of body dysmorphia, BIID may be described as an isolated, local dissatisfaction with precise body parts other than an overall distorted image of the remains in general view. The disorder usually develops early in life or during adolescence and it is usually triggered by the benign interests in amputation or disability and the interests slowly turn into destructive obsessions. BIID patients often use the description they have of feeling foreignness towards a particular body part, as being alien, uncomfortable or incomplete when that body part is present and functioning, the condition questions some basic notions of the ownership of the body, identity, and the neurological ground of self-perception. Investigation of BIID has demonstrated interactions amongst sensory processing, body schema representation and identity development, which have led to a suggestion that the condition might be a developmental anomaly of the brain systems involved in multisensory processing of body information. The infrequency of BIID and the social disapproval of the want to be an amputee has restricted past thorough studies(1). Yet, there is a growing body of neuroimaging research and case reports that have started to explain the neurobiology of this disorder that gives important information into how we associate our bodies as belonging to us and what is involved in the neural processes that have control of our physical identity. Mastering BIID is not just a matter of intellectual interest, but it raises serious medical, ethical and moral issues as well as questions of our general awareness of human consciousness and identity. The disease makes us ask ourselves some essential questions regarding the right to do with your body what you want and whether mind and body are linked or not, and to which extent a person should own his or her body. With research in the field still developing, BIID becomes a special form of insight into the depths of the neurology that defines the fundamentals of our sense of self and of our physical bodies.

2.The Evolution of Classification and Development of History

Since its first mention in medical community in the late twentieth century, the understanding and categorization of Body Integrity Identity Disorder has changed drastically. Initial case reports at the end of the 1970s and through the 1980s described people who desired amputations with the stated non-medical purposes; attempts to classify their wants were classified in the paraphilic behaviors or sexual dysfunction. Apotemnophilia is one of the more unfortunately named conditions: invented to describe then-theorized erotic obsession with amputation, this term radically misdefines both the type of condition and the intentions of those with it. This initial mishandling was causing decades of inadequate understanding and treatment strategies that usually revolved around sexual activity alteration instead of what was actually at the core of the illness neurological changes and identity related issues. With new cases having been discovered and researchers being able to discuss with more people who experienced such desires in more detail, it became obvious that sexual arousal was not a main driving force behind most of the people who had those desires(2). Rather, a more complicated image was developed of people facing existential issues of alienation against certain body parts and speaking about the feelings that some of their limbs were the thing that was alien to them and, instead of one of a part of themselves, was attached to their bodies. A shift in thinking, when the BIID was no longer understood as the paraphilia and started to be considered as the identity disorder, was a major paradigm shift in comprehension of the disease. This renaming took into account that the distress persons with BIID were feeling was also not owing to sexual dysfunction but to an overwhelming conflict between the internal body image and the outer physical reality. More advanced diagnostic guidelines have also assisted in establishing differences between conditions like the BIID and others such as body dysmorphic disorder, factitious disorder, and some other self-harm disorders. Contemporary classifications scheme acknowledge BIID, as a discrete disorder that demonstrates particular criteria, such as desire to undergo amputation or paralyze healthy limbs persistently, first appearing in childhood or adulthood, the lack of psychosis or other sever significant mental disease conditions as possible explanations of presented symptoms, and impairments or distress in proper functioning. Advocacy by BIID sufferers has also contributed to the change in BIID classification as people affected by it have attempted to make sure that their experiences are no longer stigmatized and greater perceptions of their motivations and needs are better understood. Listening to the people who live with BIID has become a topic of importance to professional groups and scholars, particularly as it can change attitudes towards studying and treating the condition, treating people with greater delicacy and respect. This multiregional cooperation has led to the problem of determining diagnostic criteria and treatment advice as well as pointing to the multifaceted nature of the ethical considerations that have to be made regarding possible interventions.

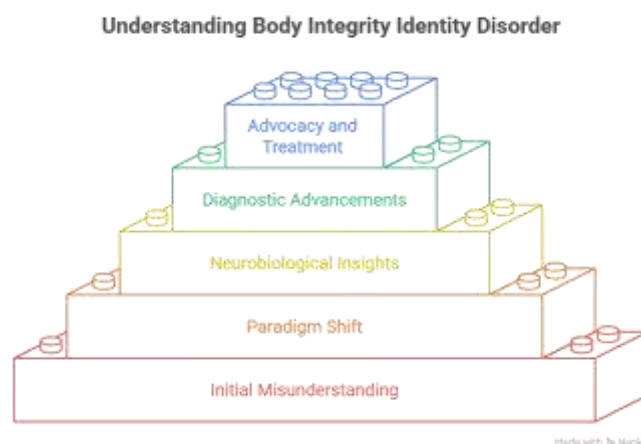


FIGURE 1 Understanding Body Integrity Identity Disorder

Recent contributions in neuroimaging technology have transformed our insights about the neurobiological mechanism of Body Integrity Identity Disorder and demonstrated particular structural and functional disturbances in the regions of the brain, key to body ownership and sensory integration. Recent studies with use of magnetic resonance imaging, functional Magnetic resonance imaging and other advanced neuroimaging tools have revealed regularities of differences in brains of people with BIID and neurotypical control variables(3). The cortical areas which have been studied specifically are the parietal cortex, the premotor cortex and the phases of the insula all of which are involved in the important role of embodiment and the body ownership and the unification of different

body parts into sensory connection. The key spatial hub and representation of the body schema, superior parietal lobule, exhibits activation based on altered patterns when BIID patients are looking or imagining having their undesired limbs. These results indicate that those neural networks that facilitate the integration of belonging the information of limbs into the whole body schema might be disturbed or improperly developed in people with BIID. Data obtained by using functional connectivity studies showed an impaired communication between brain regions that typically collaborate to guarantee continuity of body representation, which could be the reason why the individual experiences some limbs as alien or not parting of the body entirely. Premotor cortex responsible in combining sensory information to plan or command movements and helps in body ownership sensations also has shown reductions of volume of gray matter in majority of BIID patients mainly in the regions that represent the unwanted limbs. Such difference in structure might help to explain the lowered feeling of ownership and control experienced by sufferers of BIID over their affected body parts(4). Also the insular cortex which helps to process the interoceptive signals and helps to define the self-awareness, has been observed to display a different pattern of activation in the BIID patients when the affected limbs are involved in the task. Such neurobiological evidence substantiates the presumption that BIID is causally ascribed to developmental abnormalities of brain pathways involved in the representation of body but not psychological or behavioral features per se. The replicability of the results of these studies in other studies by other groups and using other methodologies indicates that BIID does enjoy a solid neurobiological basis, and that lends credibility to the experiences of people with BIID, and it helps to define BIID as a neurological rather than purely psychological diagnosis. Learning about these processes has significant implications when it comes to coming up with specific interventions as well as such research may one day result in non-surgical interventions that will help handle the root cause which is the dysfunction of the neural areas. In addition, learning about BIID gives us important information about the ordinarily occurring mechanisms of body ownership and may lead to the further development of the illness treatment (of other disorders related to the disordered body perception).

3.Lines of Therapeutic Action and Ethics

Body Integrity Identity Disorder raises some unique ethical and medical issues regarding the treatment of the condition and the debate is hot among both the healthcare and general society. Conventional psychiatric treatment together with psychotherapies, cognitive-behavioral therapy, and pharmacological approaches have proved to be quite ineffective in curbing the urge to amputate or become paralyzed which is characteristic of BIID. The inability of the current treatment to give effective relief has even prompted other people to seek such extreme options as self-mutilation to require a medically-induced amputation, or to travel to a nation where medical regulation is minimal to obtain an operation. Such desperate measures indicate the severe levels of distress that people with BIID experience and the extent to which they require proper treatment methods. The treatment option that is the most controversial is an elective amputation of healthy limbs, as it affects the very principle of medicine a healthy person should be treated with doing no harm and, whenever possible, save the healthy tissue(5). Nonetheless, case reports of patients who have had an amputation indicate that most say they feel much better after the procedure both regarding quality of life and the psychological state to the extent that some healthcare providers believe that properly chosen surgical procedures could be morally permissible in extreme situations. The formulation of the treatment plan for BIID should take numerous factors into consideration, such as the chronicity and severity of the symptoms development, therapeutic failure of conservative methods, ability of the individual to participate in the informed consent, and the risks and advantages of different intervention types. Certain healthcare systems have formulated specific guidelines of assessing BIID patients which sometimes involves prolonged psychological testing, experimentation with prosthetics or at least temporary immobilizers, or consultation with multidisciplinary teams prior to considering more intrusive options. Other strategies under exploration are neurofeedback training to change brain activity patterns in areas of brain implication of the body ownership sense, and virtual reality-based treatment which can give a person an opportunity to perceive an altered body representation, and focused brain stimulation which may need to restore normal activities of the disturbed neural mechanisms. Questions about bodily autonomy and individual agency should also be the subject of the ethics framework developed in regards to treating BIID, where the choice of the individual is both the priority and judged against possible irreversible medical procedures and potential coercion or impaired judgment(6). Even professional medical bodies do not know how exactly to establish the correct ways of treating BIID as they are still trying to establish ways to administer treatment in a caring way and at the same time consider ethical standards and patient safety. This history

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of the ever-developing treatment methods parallels the difficulty of the condition of BIID and the necessity to treat a condition that exists between the field of neurology, psychiatry, surgery, and medical ethics.

4. Methods

4.1 Subjects Recruitment and Eligibility

Discovering participants to take part in BIID studies is in itself difficult because of the distinctiveness and the stigma that is surrounded by the condition. The strategies used by researchers to recruit participants usually combine internet-based approaches, such as online discussions related to BIID communities, special medical clinics, and recommendations of medical professionals who are duly aware of the syndrome. To facilitate screening of the participants the recruitment process is usually rigorous in hopes that participants are qualified according to diagnosis criteria of BIID as they also exclude other persons that may exhibit other conditions which may exhibit similar symptoms. Possible selection criteria should be developed by researchers that should include desire to have amputation or paralysis in the last one year, no psychotic disorder, and no severe changes in the mental state. Typical exclusion criteria are an interval active substance abuse, severe depression with suicidal ideation, and other neurological disorders that may confound the results. Great consideration of ethical issues in this process should be put in place and this entails that all prospective participants of such research require to be fully aware of such goals in terms of research and must not be using the research as a way of clinically treating him or herself. The small sample is one of the challenges faced in many studies because of the low prevalence of BIID; hence researchers combine their efforts, covering various institutions and nations to meet the statistical threshold.

4.2 Diagnostic Diagnosis Protocols

The development of a reliable system of diagnostic assessments used to identify BIID is quite difficult because the criterion of diagnosing disorders has not been standardized in major psychiatric classification systems. The typical approach of the researcher is to elaborate detailed interview guidelines that help determine the occurrence, the frequency, and the severity of desires to be amputated besides seeking possible psychological causes of the pursuit. Such tests usually entail structured clinical interviews that analyze psychiatric histories, exposure to trauma, and present mental conditions(7). Most of them use the psychological validated tools to measure the body image, depression, anxiousness and the quality of life. Several assessment sessions often take place as a part of the diagnostic procedure because the dependence upon consistency of reported symptoms is demanded and the establishment of rapport with the participants is essential because they are reluctant to tell their stories completely. Researchers should critically distinguish BIID and other disorders that could have similar characteristics including body dysmorphic disorder, factitious disorders or self harm diseases. The assessment procedure should be manned by the mapping of the particular body parts when amputation desire is sought after and investigating the subjectivity of the characters or the interpretations with respect to such body parts.

4.3 Neuroimaging Methodologies

The neuroimaging technique images usually utilized in studies of BIID to establish differences in the brain that are related to the condition are structural and functional magnetic resonance imaging. The structural MRI protocols refer to assessments of gray and white matter volumes in areas that are parts of body ownership and sensory processing. A common approach to analyzing the brain is to use voxel-based morphometry in a whole-brain comparative approach in examining the structural brain variations between the BIID participants and controls. Task-based paradigms are commonly used in Functional MRI studies such that the subject sees pictures of their own bodies or is stimulated in a tactile manner and the activity of the brain observed. Such research can involve situations whereby the subjects are shown pictures of the parts of their body they want to amputate as opposed to those of other areas. The studies of resting-state functional connectivity analyze communication between various brain areas when specific tasks are not performed. Additional neuroimaging methodologies like diffusion tensor imaging can also be employed to examine integrity of white matter and interconnection between areas of the brain that are involved in body representation. There are many factors that researchers need to take into because they may cause confounding effects, these factors include age, sex, handedness, and head movement when being scanned.

The BIID research generally uses the case control studies that compare patients with BIID to healthy matched controls. Because the condition is rare, the cross-sectional design is used in many studies instead of the longitudinal one, but some researchers promote the use of a longitudinal study to examine the progress of symptoms that would allow them to learn how symptoms develop(8). The selection of control groups must be done critically using

appropriate matching of the demographic variables and the controls must not be of unusual body image concerns or an urge to be amputated. Other studies use other comparison groups, other body image disorders or amputation due to accident among other things, to more easily isolate the variables related to BIID. As a rule, experimental paradigms may involve both self report data and objective measures of assessment like measures of physiology or performance. Researchers should pay attention to emotional effects of the processes of a research, especially when the participants should be asked to concentrate on the parts of their body that they prefer not to pay attention to or have amputation wishes.

TABLE 1 Methods

Method	Details
Recruitment & Eligibility	Internet-based, medical clinic referrals, rigorous screening, exclusion of similar conditions, ethical considerations.
Diagnostic Protocols	Structured interviews, psychiatric history, psychological tools, multiple sessions, differentiation from similar disorders.
Neuroimaging	Structural MRI, voxel-based morphometry, functional MRI, resting-state connectivity, diffusion tensor imaging, control for confounding factors.
Ethical Protection	Informed consent, safety protocols, continuous monitoring, confidentiality, ethical review of research findings.

4.4 Moral Paradigm and Protection

Research on BIID has to be done with ample ethics because those who apply to the research are susceptible, and the research process may even subject them to suffering. The review boards in institutions should look very keenly in assessing the risk-benefit ratio of the proposed studies that the scientific gains must warrant the level of discomfort caused to the individuals in the study. The process of informed consent should be especially careful to not only describe research procedures but also explain that being in research did not offer any clinical benefit or access to amputation surgery. Scientists have to be prepared with procedures that will guide them on how to deal with participants who undergo high levels of distress or demonstrate suicidal thoughts when conducting the study. Most studies will involve continuous safety monitoring and might have to withdraw participants when their symptoms develop to a level that presents concerns to their safety(9). Because of the stigma of BIID, as well as the possibility of legal consequences in some locations, the anonymity of the information about the participants should be of utmost importance. Scientists should not only think about the immediate consequences of their studies but also of the further ethical consequences of their research, such as the possible misuse of the findings in order to prove or disprove this or that method of treatment of BIID.

5.Results

5.1 Magnetic Resonance Imaging Findings

Neuroimaging research into Body Integrity Identity Disorder all shows unusual anatomical constructions of the brain structure which are all very important in revealing the neurobiological basis of this disorder. The structural magnetic resonance imaging scans normally reveal smaller volumes of gray matters within certain cortical areas with the superior and inferior parietal lobules, which play vital roles in such spatial processing and representation of body schema. These volume decreases tend to be largest in the contralateral hemisphere as would be expected to be linked directly with the required body parts that the BIID patients want to be amputated. The size of gray matter volume decrease is often correlated with the length and intensity of BIID symptoms suggesting that such structural variations could either be developmental alterations predating a person to develop the condition or deformation that occurs as a consequence of the persisting altered body perception. Also, a change in the premotor cortex has been widely described, especially the ventral premotor region that has been shown to be significant in multisensory information since it has been shown to be important in integrating multisensory information in body ownership. These anatomical variations do not merely involve decrease in volumes, but rather variations in cortical volume measurements and cortical surface area, an indication that it may have a generalized developmental or degenerative processes involving body representations regions. Disrupted connections between major brain regions involved in body ownership networks are usually identified in white matter integrity analysis

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with diffusion tensor image in terms of loss of fractional anisotropy in pathways connecting parietal, temporal and frontal regions. The insular cortex has a central role in interoceptive awareness and self-perception and often it presents with structural abnormalities in BIID (there is an increase reported and in other parts of this complex brain region there is a reduction in the volume). Interestingly, there have been other studies that claim to have found compensatory structural remodeling in brain areas that were not heavily linked with the aspects of body ownership, though it could have meant that the brain is trying to fix the issue occurring in the base by using another neural route(10). These structural results give very strong clues that BIID is not a psychological but on the contrary is a real neurobiological disease involving real brain-based abnormalities and thus should be characterized as a neurological condition.

5.2 Patterns of Functional Brain Activity

Functional neuroimaging of BIID indicates unique patterns of cortical activations to help understand the neural mechanism of the perceptual changes in body perception associated with the condition of BIID. Individuals with BIID do not show similar activation patterns in their brains when viewing images of their own bodies, especially, of those limbs they want to be amputated, compared to that of their healthy control counterparts. The SPL that is normally very active during the body-ownership task is found to be activated less when the BIID patients are interested with their undesired limbs than when they are interested with those body parts that they desire to keep. This hypoactivation could be the reflection of the neurobiology of the alienation that these people experience toward certain parts of their bodies. In contrast, there are certain parts of the brain that will bear a higher activation in a patient with BIID and this can be either the result of a compensation that has been developed, or an increase in the response to body stimuli that is emotional. Changes in the activation pattern characterized the premotor cortex when engaged in tasks that involved the unwanted limbs and there are studies that showed a decrease in the level of the induced cortex during the motor-imagery tasks performed on the unwanted body parts. This observation is not unexpected according to reports of BIID patients who note that they feel fewer associations with and control over their undesired limbs. The Insular cortex, which plays a significant role in intertwining the body senses with the emotional and cognitive processes, exhibits complicated patterns of overactive and unactivated performances based on the particular task and the part of the brain under consideration. In tactile manipulation of the unwanted limbs, most BIID patients demonstrate changed activity patterns of somatosensory cortex that may indicate aberrant processing of sensory input presented in such body regions. In resting-state functional connectivity fMRI there was rendered loss of communication between brain networks in body ownership, self-referential thinking, and sensory processing. Such changes in connectivity can be used to reflect the brain underlying basis of the loss of connection between one conscious awareness and body ownership that is the hallmark of BIID. There also is altered activation patterns in emotional processing networks in BIID patients, especially in the presence of amputation related pictures indicating that the disorder has complex brain interactions in the cognitive, sensory, and emotional system. Abnormal activation patterns in the temporal cortex, which takes part in multisensory integration and body perception, can also cause the disturbance in body schema seen in BIID.

TABLE 2 Results

Category	Key Findings
MRI Findings	- Smaller gray matter volumes, especially in parietal lobules. - Altered premotor cortex activity. - Decreased white matter integrity, especially in body ownership pathways.
Functional Brain Activity	- Abnormal cortical activation patterns in response to body stimuli. - Decreased premotor cortex activity for unwanted limbs. - Altered emotional processing and somatosensory cortex activity.
Neuropsychological & Behavioral Tests	- Greater or diminished illusion effect in body ownership tests. - Impaired spatial processing. - Increased emotional reactivity to amputation-related stimuli.

5.3 Neuropsychological and Behavioral Tests

Testing on a guided neuropsychological basis of people with BIID shows distinct cognitive and perceptual predominances that augment findings of neuroimaging scans and give extra information on the functional implications of remodeled brain structure and performance. Body ownership tests utilized through illusion

techniques like those of rubber hand indicate a change in susceptibility to altered body perception such that BIID sufferers typically respond with either greater illusion effect or with diminished illusion effect as determined by the limb being tested relative to the affected limb they would like to amputate. Spatial processing tasks very often indicate more incidental impairment in BIID subjects especially when the task demands the combination of visual and proprioceptive cues regarding body posture and motion. In all these findings, there has been an associated structural and functional deviations in the parietal regions of the brain that deal with spatial thoughts. The results of attention and executive functioning tests usually demonstrate a preservation of general cognitive abilities, which undermines the claim that the related alterations in brain regions of BIID are universal, relating to gross cognitive impairment. Nevertheless, other studies show increased responsiveness to body-related stimuli in BIID patients which may be related to the building up of chronic concern over the part of the body not wanted. It has been found that the engagement of emotional processing activities reveals bizarre patterns of reactivity to body-related imagery; when it comes to amputation-related stimuli, there is a significantly increased emotional reactivity, whereas reactivity toward other emotional stimuli is retained as normal. Memory tasks usually display an improvement in recall of bodily information, especially with respect to amputation of the desired part or disability-related material, which is an indication that the disorder might include changed memory processing of personally important information dealing with body. Examination of the tactile perception is often used which is providing the modified sensitivity to touch on the unwanted limbs, and some are diminished discrimination skills or distorted application of pain in the body parts concerned. The behavioral data lends valuable support of the neuroimaging results and assistance in determining which differences in brain indicate which functional differences. The neuropsychological and neuroimaging findings collaborate in showing a more detailed portrait of BIID whereby certain connections of the brain in charge of body ownership are broken but the rest of the cognitive abilities are not too impaired.

6. Conclusion and Future work

With the backing of the innumerable research work done over the years on Body Integrity Identity Disorder, the preconceived notion that this is a neurological disorder is way beyond what one could have ever imagined, with the decades-old pop-science trivia on Body Integrity Identity Disorder getting to be dead and buried just like the proverbial Dodo bird. The hypothesis that BIID is triggered by the breakdown in brain networks that trigger body ownership and the multisensory integration including the parietal cortex, the premotor region, and insular implemented areas has considerable evidence currently. These neurological disorders seem to become evident early in the developmental process, and these disorders cannot be overcome with standard psychological treatments because the person no longer has a match between their internal physiology feeling and the actual physical structure. This uniformity of results among studies involving extractions of several research parties and research techniques has actually served to give persuasive support to the problems by persons with BIID, and it has been figured out that their suffering is based on real neurobiological disability, and does not mirror psychological pathology or bursts of interest. The scientific confirmation is significant to the extent of limiting stigma and provision of enhanced clinical care to the affected individuals. It has also been indicated in the research that there is a great specificity of BIID where abnormalities in the brain are not so much global, but restricted to the areas of the brain that represent the parts of the body that a person wants to remove, which is an indicator that it has highly focused disturbances of the neural circuitry and not general brain malfunction. Moreover, the research studies have already shown that BIID is prominent in gradient, some might want amputation and other might want paralyzation, and all these manifestations might represent various levels or forms of ionic activity in the neural circuit interference. The emerging concept of BIID has much wider implications to the field of neuroscience and it offers novel insights that will help us understand the neural processes behind body ownership and self-awareness as well as convergence of sensory inputs leading to our sense of physical identity. Such discoveries have made the conventional conceptions of the interrelationship between the mind and the body obsolete and indicated the impressive plasticity and compartmentability of neural systems that lead to body representation. It has also been pointed out by the research that it is important to hear what patients say and take directly their possible symptoms that at first may seem incorrect or weird as the scientific confirmation of BIID proves the fact that even the most real neurological conditions can manifest themselves in the most unexpected ways.

Clinical implications and development of treatment

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The neurobiological knowledge acquired as a result of research on BIID has tremendous repercussions on building better and ethically right kinds of interventions to the treatment of this difficult ailment. The realization of brain areas and networks involved in BIID creates room of precise interventions that can reverse the condition but cannot be used only to manage its symptoms. Neurostimulation TMS or deep brain stimulation, could be modified to regulate the impaired brain networks, and in theory, this could bring relief but without using surgical interventions that are irreversible. The finding of abnormalities in the neural networks connecting areas of the brain implies that treatment making strong or restoring normal brain connectivity might therefore form an effective treatment. This could perhaps be in the form of intensive rehabilitative measures or neurofeedback training regimes. As the treatment of BIID, the virtual and augmented reality technologies illicit a special promise, being capable of enabling the controlled settings to gradually alter the body perception and possibly re-train the dysfunctional neural circuits by repeated exposure to the altered body representations. The results of the research also promote the production of more advanced assessment tools that appear to be more convenient in determining the severity of BIID and the progress of treatment in terms of objective neurological results instead of subjective testimonies. The neurobiological explanation of BIID has also influenced debates concerning the matter of medical ethics of involving surgical interventions because it has offered a firmer base on which the amputation of the limb to surgically treat a limited number of patients with a poorly responsive self-satisfying disorder can be placed. This study has also demonstrated that the use of specialized care facilities and programs experienced in BIID is necessary since the path is a complex neurological, as well as psychiatric and surgical knowledge that few facilities have in general care. Furthermore, the results indicate that the best would be to intervene when still young or in the adolescence stage because at this stage neural plasticity is high and interventions would deprive the full manifestation of the symptoms of BIID. Creation of family-based intervention and support programs may also be helpful because the study has shown that BIID is usually developed in childhood and it heavily affects the family relationships and performance.

Approaches to Future Research and Methodological Development

Future BIID study has huge potential of improving our understanding on this particular condition and more broadly on how the brain works, how we perceive our bodies and neural development processes. Research due to longitudinal studies of individuals in their early manifestations of BIID through the adult age group is a research priority that would be useful to know the natural history of the disorder as well as the timeframes of intervention. Massive multicentric studies with participation of several institutions and countries will be required to address the challenge of the rarity of BIID and attain appropriate measures of statistical power that would allow unequivocal conclusions. The neuroimaging field is still developing at a rapid pace and future directions should include more recent advances in neuroimaging including high-resolution functional MRI, active neurofeedback with fMRI and advanced diffusion imaging that can offer much more detailed patterns of how the brain is built and how it functions. The combination of neuroimaging with the other modes of assessment, which entail electroencephalography, transcranial magnetic stimulation, and/or comprehensive neuropsychological testing may help in more detailed characterization of the neural dysfunction in BIID. The frontier of genetic and epigenetic study is another area that has potential to expose hereditary components that can cause the development of BIID and even present biomarkers in its early detection and intervention. Although difficult to lend itself to the making of animal models due to the uniqueness of the BIID experiences to mankind, in a bid to account the steps of development that get derailed in this disorder, emerging rather than speculative information could be drawn. Larger studies on BIID could be done using international registries and databases for researching the topic; more complex measures of factors leading to the development and progression of the symptoms could be conducted. Artificial intelligence and machine learning solutions to the data of BIID research may demonstrate the fine tendencies and associations that may be overlooked with traditional statistics and therefore a new understanding of the background phenomenon of BIID may be found. Another important direction, which should be followed by the future research, is the development and validation of the standardized BIID diagnostic criteria and assessment tools because, even now, it is lacking and it significantly impacts the further study and the clinical practice. The study of the factors within the environment, which may promote the development of BIID, such as early life experiences, exposure to traumatic experiences and influences in development, is a relevant research priority that may be used to inform preventive methods.

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Conflicts of interest

The authors have no conflicts of interest to declare

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