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Paying the price for body evolution
The role of evolution in disorders of body representation

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ABSTRACT

Since its beginning, research about cognitive representation of our bodies has debated over multiple representations models. Furthermore, recent years have seen a rise in the study of body representation disorders and related impairments. However, why human beings manifest so many deficits is still a mystery. Considering human evolution, frontal brain regions are well known for their changes in dimensions and connections. Less known is that parietal and temporal lobes encountered similar changes. These areas, especially in the right hemisphere, are crucial for body representation. Our hypothesis is that evolution of these areas determined a more varied and widespread cross wiring between the temporal and parietal lobes, increasing their communication pathways and their reciprocal influence. As such, these connections could lead to an increased probability of interconnected body and emotional disorders in humans. The prediction of this hypothesis is that all body representation disorders have an associated emotional component and vice versa. Evidence supporting the interconnection between emotional and body representation disorders derives from psychiatric diseases such as eating disorders. This hypothesis opens up new directions to understand body representation and points towards innovative solutions for the clinical treatments of body representation/emotional impairments.

Introduction

We all share one feature. Independently form where we live, what kind of culture we belong to, and all the other variables one can think about, we have only one physical body. We can modify our body in terms of external appearance. It can become bigger or smaller by eating a lot of junk food or, on the contrary, tons of vegetables. It can be decorated by changing our skin colour through tanning beds or by adding nice jewellery. It can be loved or hated as sometimes happens in eating disorders, where the body is humiliated through food misuse. Finally, we can use it or not by being active sport players or lazy television watchers. In fringe cases, we can also exchange a part of our body with somebody else, like it happens for hand transplantations. However, we cannot change it completely as we change our dresses: we do not have an additional body, like a "seasonal body" for winter and for summer.

Nevertheless, since its beginning, research on the cognitive representation of our body has debated over multiple body representations. One example for all is the famous dichotomy between the body schema and the body image, also known as the dyadic model of body representation [1]. Starting from the Nineteenth Century, descriptions of how we represent our bodies have begun to distinguish an action related representation, which includes postural and sensory information, and a conscious representation related to emotions and semantic knowledge [2,3]. This separation of concepts resembles the division of labour between the action and perception streams, or the ventral and dorsal streams model [4]. On one hand, we have concepts that are more linked to the perceptual frame (body image, sense of ownership). On the other hand, body schema and sense of agency are relatives of the dorsal stream, focused on acting on the environment. More recently, triadic models of body representation have been put forward to further define the body image concept, introducing a distinction between a body semantics and a body structural description, more concerned with the spatial localization of body parts [1]. Similarly, new developments of the concept of body schema have been proposed, involving a different role for somatosensory information [5].

Independently from the theoretical reference assumed when studying body representation, recent years have seen a rise in the study of body representation disorders. The plethora of body representation impairments ranges from brain lesion-related deficits (such as somatoparaphrenia) [6] to psychiatric conditions

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involving a disturbance in the representation of the body (such as eating disorders) [7]. Especially these last conditions have attracted the attention of neuroscience, with the development of new paradigms aimed at clarifying the role of brain substrates in these diseases, once thought as psychological reactions to traumatic events without brain-based components.

It is puzzling surveying how many conditions in human beings involve body representation disturbances in association with emotional impairments, especially if they imply a bidirectional route for symptoms (i.e. Patients with eating disorders showing a modified body image even when they are in recovery, possibly as a consequence of the prolonged emotional impact on their perception; [7]). Could it be a coincidence or is there a causal role associating these two impairments? The hypothesis proposed here is that pathologies of body representation in humans might originate from the wiring of two precise brain areas: the parietal lobe and the temporal lobe. It is of uttermost importance to understand if complex conditions involving emotional components directed towards the body might involve also a dysfunctional representation of the body itself. This would open up the opportunity to develop new treatments or to tailor existing treatments to help patients restructure their image of the self (such as transcranial Direct Current Stimulation (tDCS) protocols for stroke) [8].

The hypothesis/Theory

It is well known that brain regions have changed in terms of both dimension and connections through the evolution of humanity. The most known change from the animal brain to that of human beings is described for the frontal lobes. These areas have encountered a drastic evolution to accommodate language and executive functions abilities that are typical of humans [9–11].

It is less known that also our parietal lobe encountered similar drastic changes. Particularly, the inferior region of the parietal lobe expanded (Inferior Parietal Lobe or IPL): area PG in Von Economo maps or area 39 in Brodmann's classification are not found in the monkey brain [12]. These cortical regions are devoted to polymodal associative processes that involve responding to both visual and somatosensory stimuli [13]. Secondly, another area developed new properties: the superior temporal sulcus (STS, area 22 in Brodmann's classification). One study reports STS asymmetries in the human brain, even in the foetal period, and these asymmetries are not described in monkeys [14]. Not by chance, this area also has polymodal visual and somatosensory properties [15]. Area 22 in Brodmann's classification also expanded and auditory properties increased. These expansions took place especially in the right hemisphere of the human brain [15].

Not by chance, the parietal and temporal lobes in the right hemisphere are the brain areas for body representation, and they are dysfunctional in all disorders that involve this component [16–18]. The idea that the evolution of these areas is responsible for body representation disorders shall not be taken as a localization of a disease. Rather, evolution and expansion of these areas determined a more varied and widespread cross wiring between the temporal and parietal lobes, increasing their communication pathways and increasing their reciprocal influence [19] (Fig. 1). Exactly the development of these connections could lead to an increase probability of interconnected body and emotional disorders in humans, rather than a focal change in a unique brain substrate.

Theories that support connection between body representation and emotions take into account a "bottom-up" direction, referring to the so called "material me" [20] instead of a holistic body representation. In 2002, Craig suggests that interoceptive sensations are the basis to build a subjective sensation and emotions [20]. Similarly, Damasio et al. [21] propose that emotions arise from an evolutionary mechanism functional for survival and implicated in maintaining homeostasis. Further emotions depend on structures related to the representation of the physical body according to these authors. Taken together, this evidence supports a functional relation between the physical body state representation and emotions. However, it does not clarify what happens at the "higher" level of body representation. It is plausible to think that, at this level, not only basilar bottom-up mechanism are implicated (i.e. interoceptive sensations) but also higher cognitive processes (i.e. cognitive amplification of interoceptive signals). The connection between emotions and body representation could be present in humans thanks to an increased connectivity between the right parietal and temporal lobes (Fig. 2).

This idea is also highly related to that of anatomical proximity or proximal contiguity. The concept of proximal contiguity is widely discussed in the (debated) "The Tell-Tale Brain: A Neuroscientist's Quest for What Makes Us Human" book by Ramachandran (Chapter 3) [22]. While the scientific controversy on oversimplification that the book might suffer is out of matter here, the concept and its description have an enormous value if one wants to understand the above-mentioned matters on body representation and evolution. Anomalous cross – wirings between brain areas have been suggested for some neurological conditions. This is the case of synaesthesia [23]. In this condition, individuals experience sensations in one modality when a second modality is stimulated. For instance, a person can experience a specific colour every time she encounters a grapheme (i.e., the letter "b" may be represented in association with the colour green). The anatomical proximity can explain synaesthesia as colour and visual grapheme areas in the brain are both in the fusiform gyrus and well connected to each other [24]. Anatomical proximity has also been called into cause for Capgras delusion, a condition in which the individual is convinced that his relatives have been substituted by an impostor [24]. Impairments in this condition spread over several tasks related to face perception and not only confined to the recognition of a familiar face [25,26]. Again, the neural basis of these tasks involve areas that are widely intercommunicating [24]. Paraphrasing a sentence: "Can it be a coincidence that the most common form of body representation disorder involves an emotional component – the reverse being also true - and the brain areas corresponding to these are right next to each other [and highly connected]?" (Modified from [23]).

In summary, it appears more than plausible that without the evolution of our fine graded motor and emotional abilities, psychopathological conditions related to body representation would have never existed. These conditions could be the price we pay for being able to understand complex social situations and for being able to sew small things. As Peter Brugger noticed in his 2012 paper "Species have evolved to survive in all manner of barren and inhospitable environments and those that did survive have all reached a degree of specialisation that makes them unique in some way or another" (pag. 357) [27]. Our evolution made us unique as well as other animals, and, as well as them, we pay the price of this uniqueness.

Importantly, psychopathological conditions related to body representation affect only part of the population, and not every human being. However, the more time passes the more different subcategories emerge and new conditions are identified. While it is true that they might simply have been underestimated, there is no experimental proof they already existed as they manifest today. In any case, these complex conditions have been proven impossible to study unless all accounts, biological, psychological and social, are considered. This reasoning applies equally to well-known body representation disorders such as anorexia nervosa, bulimia, binge eating and eating disorders in general as well as to some less