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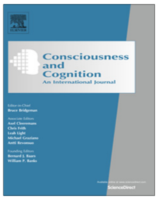

The virtual bodily self: Mentalisation of the body as revealed in anosognosia for hemiplegia

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ABSTRACT

Despite the coherence and seeming directness of our bodily experience, our perception of the world, including that of our own body, may constitute an inference based on ambiguous sensory data and prior expectations. In this article, I apply a ‘psychologised’ version of the recently proposed free energy framework to the understanding of certain disorders of neurological unawareness in order to examine how inferential processes may determine our body perception. I specifically consider three facets of body perception in such disorders: namely, the ‘external body’ as inferred on the basis of exteroceptive signals and related predictions; the ‘internal body’ as inferred on the basis of proprioceptive and interoceptive signals and related predictions; and lastly the ‘impersonalised body’ as inferred on the basis of signals from social and third-person perspectives on the body and related predictions. Several conclusions will be drawn from these considerations: (a) there is a deep interdependency of prior beliefs and sensory data; as the brain uses sensory data to update its virtual model of the world, lack or imprecision of sensory prediction errors may lead to aberrant inferences influenced disproportionally by outdated, premorbid predictions; (b) interoception and interoceptive salience have a unique role in our inferences about body awareness and (c) social, ‘objectified’ prior beliefs about the body may have a silent but potent role in our bodily self-awareness. Finally, the article emphasizes that our learned, virtual model of the body is depended on the nature and thus integrity of the very body that allowed the model to be formed in the first place.

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1. Introduction: the ‘here and now’ as inference

Remembering the past, and being able to project oneself in the future, allows the mind to escape the psychological ‘here and now’ of experience. Studies in psychology have long established that we do not only project our current self into the future to build a kind of ‘as if’, imagined future self but we also reconstruct our past self in our memories (Bartlett, 1932). Despite the incredible storage capacity of human memory, what we remember in the now is not always what took place in the past. Instead, the autobiographical incidents that we experience as veridical, coherent and self-defining are frequently unconscious collages of previous recollective attempts, fragments of experienced events, currents thoughts and long term goals (Conway, 2005). In this sense, we have come to understand our autobiographical self as actively, yet unconsciously inferred on the basis of imperfect memory data and current expectations.

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A similar idea for the nature of our experience of current reality, our embodied perception of the world and ourselves in it, has also being long proposed in psychology (e.g. Gregory, 1966). Despite the coherence and seeming directness of our experience, our perception of the world may constitute an inference based on ambiguous sensory data and prior expectations (von Helmholtz, 1878/1971). However, this idea is less established, perhaps given its counterintuitive nature and complex, philosophical implications. We experience the world via our body and the experience of the latter in the 'here and now' is considered as a fundamental aspect of our self-consciousness; our bodily self is the foundation upon which our 'autobiographical', 'narrative' or 'extended' self is built (Gallagher, 2000). If our bodily self is an inference, then our ability to perceive the world and ourselves veridically is called into challenge (see Clark, 2013 for discussion). Leaving aside the majority of the long and complicated philosophical discussions on the nature of reality and our capacity to perceive it, in this paper I will explore similar ideas from the point of view of a recent, influential theory from computational neuroscience. The theory aims to define the idea of perceptual inference using concepts from theoretical physics and mathematics and also aims to ground the same idea on biology and particularly knowledge about the workings of the brain. In the current paper, I will not address the issues of interest in mathematical ways. Instead, I will use a 'psychologised' version of the free energy framework in order to examine some ideas regarding neurological unawareness and ultimately bodily self-consciousness. Specifically, I will use clinical observations, behavioural and neural data from a specific neurological aberration of self-awareness, namely anosognosia for hemiplegia, to explore the possibility that our bodily self-awareness is normally imperfect, in the sense that it is based on a set of inferences about the hidden causes of sensorimotor signals. I also hope to demonstrate that the study of the pathologically exaggerated ways in which we may infer the experience of our own body, can provide insights into the mechanisms of normal perceptual and active inference, and particularly the predictive and social nature of motor awareness.

2. The free energy framework

The starting point of the 'free energy framework' (Friston, 2005) is that humans are biological, self-organising agents that need to occupy a limited repertoire of sensory states for homeostatic reasons (e.g. humans need certain ranges in environmental temperature in order to survive). However, due to the inherent ambiguity and uncertainty of the signals an organism receives from the world, we risk finding ourselves in dangerous states for longer periods than those we could biologically sustain (e.g. in cold climates). We thus need to be able to predict (infer) the causes of our possible sensory states despite the limited or noisy information available to our sensory organs (von Helmholtz, 1878/1971). The framework proposes that our brain engages in a form of probabilistic representation of the causes (e.g. the weather) of our future states (e.g. our temperature) on the basis of noisy sensory data; in other terms, it maintains hypotheses ("generative models") of the hidden causes of sensory input. Furthermore, it uses such input to constantly update its models, so as to reduce its representational errors over time and thus ultimately minimize the risk of surprise (unpredictability, see below for mathematical definition). From a psychological point of view, I will refer to the formation of such models as the 'mentalisation' of sensorimotor signals. Although the term mentalisation is traditionally used in psychology to refer to our cognitive ability to infer the mental states of others and our own, I think the two terms are related (see also Kilner, Friston, & Frith, 2007). In fact, the use of the term 'mentalisation' in this article is intending to ground this traditional concept in its embodied origin.

Returning to the biological level, the free energy framework is biologically constrained by the so-called 'predictive coding' models of perception, stemming primarily from biological and behavioural studies in visual perception, with supporting evidence generated in various modalities (e.g. Henson & Gagnepain, 2010; McNally, Johansen, & Blair, 2011). These suggest that a constant filtering of sensations by top-down predictions and a parallel updating of the latter based on prediction errors (signals representing the mismatch between predictions and sensations), with the ultimate goal of minimizing prediction errors, is an imperfect but highly efficient means of perceiving sensations (Rao & Ballard, 1999). Our brain is assumed to achieve the minimisation of prediction errors by recurrent message passing among hierarchical level of cortical systems, so that various neural subsystems at different hierarchical levels minimize uncertainty about incoming information by generating a prediction (or a prior belief, see below) and responding to errors (mismatches) in the accuracy of the prediction, or prediction errors. Such prediction errors are passed forward to drive the units in the level above that encode conditional expectations which optimize top-down predictions to explain away (reduce, inhibit) prediction error in the level below until conditional expectations are optimized. Such message passing is considered neurobiologically plausible on the basis of functional asymmetries in cortical hierarchies; prediction errors are thought to be conveyed via feedforward connections from lower to higher levels in order to optimize representations in the latter. Predictions from higher-levels are transferred via feedback connections that have both driving and modulatory characteristics and can suppress prediction errors in lower levels. This hierarchy is thus reciprocal but asymmetric and models the nonlinear generation of sensory input (Adams, Shipp, & Friston, 2013).

Based on such hierarchical, perceptual schemes, the free energy principle, rests upon the idea that the brain as a whole works as an Helmholtzian inference machine that is trying to optimize its own model of the world by actively predicting the causes of its sensory inputs (Friston, 2005). Moreover, this inferential process is mathematically understood in Bayesian terms (Bayes' theorem describes an optimal procedure for updating the probabilities assigned to a hypothesis in the light of new evidence), in the sense that it relies on a combination of prior beliefs (probability distributions over some unknown cause excluding any sensory data) and new sensory data to update prior beliefs and generate posterior beliefs (probability distributions over some unknown cause after data have been received). Furthermore, in the free energy principle this hierarchical minimization of prediction errors is understood as a minimization of free-energy on the basis of the formal defini-

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