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# Locked-in syndrome: a challenge for embodied cognitive science

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**Abstract** Embodied approaches in cognitive science hold that the body is crucial for cognition. What this claim amounts to, however, still remains unclear. This paper contributes to its clarification by confronting three ways of understanding embodiment—the sensorimotor approach, extended cognition and enactivism—with Locked-in syndrome (LIS). LIS is a case of severe global paralysis in which patients are unable to move and yet largely remain cognitively intact. We propose that LIS poses a challenge to embodied approaches to cognition requiring them to make explicit the notion of embodiment they defend and its role for cognition. We argue that the sensorimotor and the extended functionalist approaches either fall short of accounting for cognition in LIS from an embodied perspective or do it too broadly by relegating the body only to a historical role. Enactivism conceives of the body as autonomous system and of cognition as sense-making. From this perspective embodiment is not equated with bodily movement but with forms of agency that do not disappear with body paralysis. Enactivism offers a clarifying perspective on embodiment and thus currently appears to be the framework in embodied cognition best suited to address the challenge posed by LIS.

**Keywords** Embodiment · Body · Enactivism · Locked-in syndrome · Extended cognition · Sensorimotor approach

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## 1 Introduction

Proponents of embodied approaches in cognitive science claim that cognition is not brain-bound but relies crucially on bodily activities, processes, and structures. This overarching claim still allows for different interpretations that roughly correlate with the variety of meanings given to terms like "the body" or "cognition", and the way that qualifiers such as "crucially" are construed. Over the past two decades the term "embodied" has been used elastically to refer to anything from ideas about how bodily action formats neuronal representations (Goldman and Vignemont 2009; Gallese 2010; Goldman 2012) or helps reduce computational loads (Wheeler 2005, 2010; Wilson 2004; Clark 1997, Clark 2008a, b), to accounts of the role of bodily schemas in mental skills (Lakoff and Johnson 1999; Núñez 2004), the body as providing a pre-reflexive sense of self or perspectival ownership (Zahavi 2005; Gallagher 2006; Albahari 2007), theories of perception based on bodily action (O'Regan and Noë 2001; Noë 2004), and radical views of the living body as the central locus of all significant activity (Varela et al. 1991; Di Paolo 2009; Thompson 2007). This variety suggests an apparent lack of shared principles and concepts that curtails the chances of embodied cognitive science bringing about a true shift away from traditional views (Shapiro forthcoming).

There have been several attempts to systematize the field of embodied cognitive science (Wilson 2002; Ziemke 2003; Anderson 2003; Rohrer 2007; Shapiro 2011; Gallagher 2011; Goldman 2012). In this paper we do not provide another review comparing different embodied approaches to each other. We rather aim to contribute to conceptual clarification within embodied cognitive science by confronting different perspectives against the empirical evidence of largely unimpaired cognitive capabilities in situations of drastic reduction of bodily possibilities; more specifically, the case of Locked-in Syndrome (LIS).

LIS is a severe medical condition in which a patient is globally paralyzed. There is almost no voluntary muscle movement, and normal communication is impossible (Plum and Posner 1966; Bauby 1997; Laureys et al. 2005). Three states of LIS have been classified: the *incomplete* state with global paralysis except for head- and sometimes finger movements, the *classical* state (CLIS for classical locked-in syndrome), in which ability for vertical eye movements and blinking remains, and the *complete state* (TLIS for totally locked-in syndrome), in which the patient's body is completely paralyzed and not even eye movements are possible (Bauer et al. 1979). Despite this impairment, LIS patients are considered fully conscious and their cognition widely unaffected (van León-Carrión et al. 2002; Schnakers et al. 2008). Their minds are described as 'trapped' within their bodies (Bauer et al. 1979; Inci and Özgen 2003; Laureys et al. 2005).

A paralyzed body without a significant loss of cognitive skills poses a challenge to embodied cognitive science. If embodiment is crucial for cognition, how can we make sense of a person who appears to be cognitively intact despite severe bodily impairment? Does the evidence show that the body plays no fundamental role in cognition? We do not think so. We think that such questions highlight the conceptual confusion at the heart of embodied cognitive science. Rather than being a reason to dismiss the body as a crucial factor for cognition, LIS invites embodiment researchers to make explicit the notion of the body they defend and the extent to which it matters for cognition.

In what follows we elaborate on the LIS challenge to embodied cognition by anticipating some immediate reactions that turn out to be strategies that avoid the most productive aspects of the problem. We then offer a more refined version of the challenge which we use to guide our examination of the concept of the body in three current perspectives: 1) the sensorimotor approach (O'Regan and Noë 2001; Noë 2004), 2) extended functionalism (Clark 1997, Clark 2008a, b; Wheeler 2005, 2010; Wilson 2004), and 3) the enactive approach (Varela et al. 1991; Di Paolo et al. 2010; Thompson 2007).

On the basis of this assessment we argue that the latter is the framework that seems best suitable to meet the LIS challenge to embodied cognition.

## 2 The LIS challenge to embodied cognition

The idea that LIS poses a challenge to embodied cognitive science has seldom been made explicit in the literature. But versions of it have been floating around in the background of scientific discourse even though only in the form of an "informal criticism"; as Anderson (2003) observes:

> One informal criticism—informal because although the objection has come up in nearly every discussion of EC[embodied cognition]-related research I have been involved in, I have not seen it worked out in detail in print—is that EC cannot be true because the physically disabled are obviously able to learn, acquire concepts, and communicate. If concepts were, indeed, related to, or their contents depended upon the specific physical capacities of embodied agents, then there ought to be detectable differences in the conceptual repertoire of differently abled individuals; yet there are no such differences (Anderson 2003, p. 113).

Here the challenge presents itself in a radical but, as we will argue, also shallow version which is why we call this the *crude challenge*: if the neural and non-neural body is crucial for cognition (as embodied approaches claim), then the cognitive capacities of LIS patients should be, contrary to evidence, fundamentally impaired. This version of the challenge sweepingly ignores the varieties of claims made by embodied cognition. Nevertheless, it offers a counter-argument for cognitive scientists who question embodied approaches per se: Because cognitive function in LIS patients is preserved, the body *cannot* be crucial for mental activity. Without due differentiation, the only statement upon which all the embodied perspectives seemingly agree, turns out on this view to be empirically false.

While this sweeping attitude towards the challenge may construe embodiment claims too narrowly in order to reject them, there is an easy but similarly crude, and perhaps too liberal way to respond to the embodiment-skeptic stance. A defender of embodied cognition can adopt a kind of *developmental response*: It seems likely that learning to move in the world, bumping into things, feeling effort, etc. are embodied experiences that deeply influence our capabilities to understand, say, causality, intentions, plans, goals, and so on. Evidence suggests that several bodily schemas underlie the culturally mediated use of metaphors (e.g. Lakoff and Johnson 1999) and mathematical skills (Núñez 2004). And a history of bodily interpersonal engagements since

infancy is the enabler of various social skills and the ability to take the other's perspective (Reddy 2003). So a rough-and-ready reply to the crude challenge could simply be: The body plays a crucial role in the development of cognitive skills. Even in cases when the body is impaired and cognitive skills unaffected, we cannot ignore the body in understanding how such skills have come about. Note that "developmental" here denotes a *causal-historical* relevance of the body. There is a broader sense of development, namely as an ongoing process extended in time whose logic and principles still regulate plasticity even after skill has been established. A much stronger claim about the role of embodiment could be made from this perspective on developmental processes, one that is not solely historical. What we would like to consider here is not this stronger sense of development as an ongoing process, but a response to the challenge that relies on a narrow reading that reduces the body's relevance to a causal factor in the history of development of a cognitive skill. We thus propose to refer to this possible response as the *narrow developmental* reply.

There are at least two dangers with this strategy. While it seems undeniable that a compelling case could be made for the enabling role played by bodily factors in the development of some cognitive capabilities, it is far from clear that the case can be made convincingly in general. Adopting this kind of response forces us to empirically determine case by case whether the body plays or does not play a role in a developmental history (as well as determining what counts as a crucial role—a far from trivial question). Methodologically, attempts at a general statement concerning the role of the body in cognition would run the risk of becoming a collection of "just-so" stories—a criticism already raised against the adaptationist program in evolution (Gould and Lewontin 1979) whereby the mere formulation of a plausible story replaces an empirically supported examination. The undesirable result of adopting such a strategy would be an embodied cognitive science that dogmatically assumes a developmental role for the body as a general rule.

The other worry with the narrow developmental response is that embodiment-skeptics can easily argue that a developmental role of the body, while necessary along a given historical path, is merely contingent, and that other developmental routes are possible that could causally arrive at the same results with bodily factors playing no important role in them (Shapiro 2011, p. 160). If, for instance, some of our mathematical abilities are supported by a history of bodily coping with objects and interacting with people but can, at the same time, (for the sake of argument) be described in purely formal, disembodied terms, why could these capabilities not be constructed in an artificial cognitive system using the resulting formalism, obviating the embodied history that led to them in the human case?

In attempting to avoid the stark rejection of embodiment claims made by the crude LIS challenge, the narrow developmental response rescues a role for the body as a historically enabling factor. However empirically interesting this claim turns out to be, the strategy is eventually self-limiting since it avoids positing a positive role for the body in the disposition and actual enactment of cognitive performance. Claiming a historically causal role for the body leads to an "overly lenient definition of embodiment" (Goldman 2012) and runs the risk of trivializing embodiment as a true alternative to traditional, brain-bound views (Block 2005; Shapiro 2011).

We believe that both, the crude challenge and the narrow developmental response avoid the key issue. These reactions do not question the linkage between embodiment

and cognition that, as we have said, remains in need of clarification. The crude version of the challenge implicitly presupposes a particular conception of embodiment, namely that embodiment is about (neuro-muscular) movement, which is constantly required for cognition. The narrow developmental response then quietly accepts this presupposition and seeks a way of accommodating it by saving at least a historical role for the body. It is, however, misleading to take this implicit conception of embodiment as representative of the whole of embodied cognitive science.

To consider bodily skills and actual movement as historically relevant for cognition obviously corresponds with some theories of embodiment. Yet to take this claim as paradigmatic make us overlook the variety of embodied approaches offering much stronger claims about the body. In fact a number of embodied perspectives hold that fundamental aspects of all cognitive skills cannot be understood without recourse to some essential and movement-transcending aspects of embodiment, not only in terms of a historical progression, but also in terms of the disposition and enactments of such skills, both in a causal and constitutive sense (Shapiro 2011, p. 160). It is with respect to these stronger conceptions of embodiment that the challenge posed by LIS should be evaluated.

From a theoretical perspective, and in the current context, the LIS challenge turns out to be more than a key scientific problem; it is also a demand for embodied approaches to work out their basic tenets by specifying which aspects of the body are relevant for which aspects of cognition and in what manner. We thus propose the following refined version of the problem: Given that LIS patients seem cognitively intact despite the lack of bodily movement, what can we say about the importance of various aspects of the body not just for the historical development but also for the disposition and current enactment of cognition? Which specific aspects of the body can be considered essential for the mind as opposed to only historically relevant? Are these aspects problematic in the face of LIS evidence?

## 3 Methodology

We have suggested that any defender of embodied cognition agrees with the statement: *The body is crucial for cognition*. But what does this statement amount to? Deciding on how to interpret this statement will reveal the differences between the various approaches. More specifically we can ask: 1) What is meant by *body*? 2) What is meant by *cognition*? And 3) what is meant by *crucial*? These questions inform our comparative methodology. The first question leads us to examine issues such as what are the features that identify a body as such, i.e. the principles by which we can distinguish the body from the non-body. The second question asks what counts as a cognitive process as opposed to one that is non-cognitive. The third question looks at the relation between these two concepts (body and cognition) and it also considers the strength of the claim that the body is crucial for cognition. Is the claim about causal relations—either historical or contemporaneous, contextual or enabling—or is it about relations of constitution.

We have selected for our analysis the sensorimotor, the extended functionalist, and the enactive approach to embodiment because we believe their conjunction covers a wide range of conceptual possibilities, subsuming (for the context of this discussion) various other perspectives. In section 4, we consider, first, independently what each approach has to say about the body and to which extent it is said to be crucial for

cognition. In the second step, we confront each approach with cases of LIS. The motivation behind this is to gain a fresh and un-biased account of each approach. Instead of comparing against the explanatory standard of a single preferred background approach to cognition each conception is taken seriously in itself by considering what it would amount to were it to become the general view on embodiment. Different aspects of LIS, including its origins, the use of Brain-Computer Interfaces (BCI) and quality of life reports will be examined during the discussion. In the third and final stage (section 5) we take stock and compare between theories the different concepts of the body that emerge and how they fare in the face of the refined LIS challenge.

## 4 Assessing embodied cognition in the context of LIS

### 4.1 Movement and action in the sensorimotor approach

The sensorimotor approach considers the role of the active moving body in bringing forth perceptual experience (O'Regan and Noë 2001; Noë 2004). This approach has sometimes also been referred to as enactivism and it is, in fact, partly compatible with the enactive approach we will discuss below. However, following Thompson (2007, p. 260) we refer to it as the sensorimotor approach in order to distinguish it from the more complex and autonomy-based version of enactivism.

According to the sensorimotor approach, perception relies on movement and the mastery of lawful relations that hold between sensory changes and motor activity (so-called sensorimotor contingencies). Perception, in this approach, is a form or an aspect of action and cognition in general is partly constituted by the coupling between body and environment, in contrast to internalist views that place cognition as an activity of the brain. Even though the sensorimotor approach is restricted to perceptual experience some researchers have recently made an extrapolation from the case of perception to cognition in a wider sense. For Engel and colleagues, for example, "cognition is understood as capacity of generating structure by action" and actions are "grounded in basic sensorimotor behaviors" (Engel et al. 2013, p. 203). A similar "motor theory of thinking" in accordance with James (1890) is adopted in recent clinical research on totally locked-in patients and BCI use (Birbaumer 2006; Kübler and Birbaumer 2008).

While the sensorimotor approach is clearly a theory of the *moving* body it does not offer an explicit definition of the body (Fingerhut 2012). For this reason, with regards to our first question—what features identify a body—we must rely on indirect indications of what could count as an answer from a sensorimotor perspective. O'Regan and Noë state that "differences in our bodies (and thus in sensorimotor contingencies) will make a difference to our experiential states" (O'Regan and Noë 2001, p. 1013). For example, "a crucial fact about vision is that visual exploration obeys certain laws of sensorimotor contingency. These laws are determined by the fact that the exploration is being done by the visual apparatus" (ibid, p. 941). In contrast, you are able to feel the shape of a specific object's surface "by your active touching (probing, prodding, stroking, rubbing, squeezing) with your hands". The "tactile impression" does not only rely on "sensations in your hands and feet" but on their "movement through space" (Noë 2004, p. 15). Sensorimotor contingencies would then be regularities in the co-variation of sensory and motor activity (see also Buhrmann et al. 2013 for a critical

discussion of this concept). They are found in principle in all perceptual domains (O'Regan and Noë 2001, p. 943). These considerations suggest that for the sensorimotor approach the key aspects of a body are particular sensorimotor structures that are able to be attuned to the laws of sensorimotor contingencies (and their immediate supporting systems, e.g., the musculo-skeletal configuration and neuro-physiology of the eyes or hands) and an active engagement in an ongoing coupling with the world that is the process by which mastery of the laws of sensorimotor contingencies can take place. Even if other factors may be relevant, we interpret that at least these aspects of the body are clearly critical for this approach. Note that we do not rule out that there could be a future, more precise definition of the body provided by the sensorimotor approach. But based on the current claims of this approach, such a definition, we believe, cannot contradict what presently seem to be the key aspects of embodiment that we have identified (the presence of sensorimotor systems and structures, susceptible of adjustment according to the laws of sensorimotor contingencies and an active engagement with the world).

We now turn to our second question: what counts as a cognitive process? For the sensorimotor approach, cognition "is not something that happens in us", but "something that we do … in our dynamic living activities" (Noë 2004, p. 64) and it involves "the active engagement the perceiver undertakes with the environment" (O'Regan and Noë 2001, p. 962). In contrast to the traditional cognitivist view, cognition for the sensorimotor approach is therefore not information processing in the brain, but a dynamical process involving the agent's active coupling to the environment. This enlarges the locus of cognition from brain, to brain-body-environment and is opposed by an emphasis on active world-engagement to a view of cognition as passive information processing. However, there is a range of processes that usually do not count as cognitive (such as respiration) that would similarly fall within the scope of such a wider conception. In other words, even though cognition from the sensorimotor perspective is circumscribed differently than in traditional approaches, it remains underspecified. Similarly as in the case of the first question, the aspects that we have identified (the broadening of the constitutive space of cognition and the emphasis on active engagement) are unlikely to be altered if sensorimotor theorists could offer a more specific definition of cognition.

We now consider our third question—what is the relation of body and cognition and to which extent is the body relevant for cognition. The sensorimotor approach is ambiguous about this question. Shapiro distinguishes between a *stronger* and a *weaker* interpretation of the sensorimotor claims: "On the stronger interpretation, the exercise of sensorimotor knowledge requires that one *actually* practices those actions that reveal sensorimotor contingencies." (2011, p. 168). For cognition active engagement as well as at least minimal movements of the body are required contemporaneously. This reading is supported when O'Regan and Noë say that perceptual experiences involve "active engagement the perceiver undertakes with the environment" (O'Regan and Noë 2001, p. 962) and Noë adds that "some minimal amount of eye and body movement is necessary for perceptual sensation" (Noë 2004., p. 13). It seems that this stronger reading of the sensorimotor approach implies that without actually engaging in bodily activity (movement of eyes for instance), there is no perceptual experience.

But the sensorimotor approach also allows for a "weaker interpretation" according to which "exercise of sensorimotor knowledge consists only in the *potential* to perform

those actions that define a class of sensorimotor contingencies" (Shapiro 2011, p. 168). What matters here is that at some point in the past sensorimotor contingencies emerged through bodily engagement. Visual experience in the present moment depends on applying that knowledge of those contingencies, but not on actual bodily engagement that has led to this knowledge. In order to perceive a solid object as having a back surface, for instance, we use our 'knowledge' about how we should move our body around the object (Noë 2004, pp. 11–13). This know-how about the "possible input/output relationships" (O'Regan and Noë 2001, p. 943) forms part of our current perception of the object. The approach thus puts an explicit emphasis on the important role of sensorimotor skills for perception. But the mastery of those skills, i.e. the practical 'knowledge', however, is not obviously identified with any specific characteristic of the *body* in the sensorimotor approach. In fact, it is sometimes interpreted to be of a traditional representational kind (Hutto 2005; Aizawa 2007; Roberts 2009). It thus seems safe to say that the weaker interpretation would involve a *historical causal* claim about the role of bodily engagement for cognition.

We are not interested here in defending either interpretation. In what follows we explore, in the context of LIS, how the sensorimotor approach would fare on each of them. The result of the analysis will not depend on whether Shapiro's distinctions should be interpreted causally or constitutively.

In order to understand what the sensorimotor approach might mean by "the body is crucial for cognition" in the stronger claim, let us now consider the sensorimotor approach in the context of the classical state of LIS (CLIS) in which the patient's body is immovable as a whole and bodily exploration of the environment restricted to the small field of vision.

According to Noë there is "strong empirical evidence that more thoroughgoing paralysis—for example, of the eyes themselves—would cause blindness" (Noë 2004, p. 13.). On the strong reading, this seems to reaffirm that the sensorimotor approach considers sensory and motor processes and structures—specifically *neuro-musculo-skeletal* activity—as playing an indispensable role for cognition (which can either be constitutive or causal enabling but not merely historical). From such a perspective CLIS patients can still be seen as relying on some sensorimotor interactions since eye blinking and saccadic movements are preserved. However, if this claim was paradigmatic of an embodied approach to cognition we would not be able to account—not in terms of embodiment—for cognition in cases where there can be no movement and no active engagement. This would be the case for instance in patients with total LIS (TLIS) who are unable to move at all. For such patients, the stronger sensorimotor reading implies that they cease to be cognitive, as one of their two required elements (a body composed of sensorimotor systems capable of actively engaging with the world) would be absent. This is, by the way, an interpretation already adopted in current clinical research. Kübler and Birbaumer indeed argue that global paralysis might lead to a "cessation of voluntary cognitive activity, goal directed thinking and imagery" (Kübler and Birbaumer 2008, p. 5245).

A similar difficulty arises when giving account of patients who use BCI technologies both in the CLIS and TLIS states (Birbaumer and Cohen 2007, Dobkin 2007). Patients using BCI are responsive, show intentions, make plans, and solve problems. Such activities are likely to be included in all of the accounts of embodied cognition discussed in this paper so that we can safely say that BCI engagements with the environment involve cognitive processes. And yet, these processes are achieved

without relying on active musculoskeletal and sensorimotor engagements. Instead, during BCI interactions, patients modulate their own brain activation patterns to communicate and directly control external devices (Birbaumer et al. 2003). Cortical areas that usually contribute to exert control on the motor neurons now additionally assume the role of the motor neurons and thus become themselves the "final product" of the central nervous system (Wolpaw 2007, p. 616).

Finally we need to consider the case of eye-movements in CLIS. While it is clear that these movements can be co-opted for a variety of different functions apart for those that subserve visual perception (they can be used to point, to signal agreement or disagreement, etc.) it is unlikely that this narrow channel of active sensorimotor engagement would suffice to sustain the cognitive capabilities in LIS patients. It remains an interesting empirical issue, not directly central to our discussion, the extent to which eye-movements, being the sole possibility of spontaneous active engagement and expression in the absence of BCIs, are unintuitively involved in various cognitive processes in LIS. We can assume that if sensorimotor engagement is required for cognition, such a massive reduction in the possibilities for engagement would be expected to correlate with equally important deficits in perception and cognition, which is not the case.

As a consequence the strong sensorimotor approach is unable to meet the LIS challenge. A possibility that remains open for the sensorimotor approach would be to demonstrate that the skillful use of BCI is not merely revealing, but required (either constitutively or causally enabling), via its patterns of use, of cognitive activity in a similar way as neuro-muscular patterns would have been (thus become effectively part of the body according to the reply to our first question). This is an interesting but far from obvious claim; it would have to be judged on its merits, but this is beyond the scope of this paper. It would still have to satisfy the quantitative and qualitative skepticism we have mentioned for the case of the role of eye-movements. On the stronger interpretation embodiment in the sensorimotor approach requires actual neuro-musculo-skeletal activity consequently, for the reasons presented above, this approach would be too restrictive to account for cognition in LIS. Cases of skillful BCI use show that cognitive activity can exist without involving neuro-muscular structures associated with movement.

Let us now consider the second, weaker interpretation of the sensorimotor approach, according to which, perception relies on the possession or mastery of sensorimotor bodily skills without requiring action or movement to be instantaneously exerted (Shapiro 2011, p 168, O'Regan and Noë 2001, p. 945). Critics have argued that cognitive processes such as "dreaming, meditation, tachistoscopic vision, hearing, pain, perception during paralysis, hallucinations" (O'Regan and Noë 2001, p. 1015) are evidence that not all instances of perception require movement and action. O'Regan and Noë's response to those worries fosters a weaker interpretation:

It is not our claim that action is necessary for experiencing. Our claim, rather, is that knowledge of the ways movements effect sensory stimulation is necessary for experience. It is not movement as such, but the consequences of potential movement that play a role in our view (O'Regan and Noë 2001, p. 1015).

On this view, actual exercise of sensorimotor skills involves the use of "particular sets of sensorimotor contingencies" that—in a vocabulary reminiscent of classical information processing—have previously "been recorded and will be latent, potentially available for recall". Action matters only insofar as the person previously had the ability to actively exert "control over her visual input" (O'Regan and Noë 2001, p. 1015). In contradiction

with the stronger interpretation, the mastery of sensorimotor contingencies thus would not require active movement since, as O'Regan and Noë state (equivocating personal and subpersonal categories) "the brain has mastery of all these sensorimotor sets" (p. 945). An implication of such statement is that once the brain 'has' the practical 'knowledge' this can be exercised without further active engagement or bodily movement.

How does the sensorimotor conception of the body fare in accounting for the challenge posed by LIS? Both, the weak and strong reading of the sensorimotor approach reveal limitations to account for the challenge posed by LIS. In the case of the stronger interpretation (both actualized action and acquired skill are required for perception) we can easily see that the sensorimotor approach implies that LIS patients should largely be unable to perceive since they are unable to move. The strategy of extending the necessary role of action understood as implying musculo-skeletal activity to cognition in general, encounters serious problems when confronted with the LIS evidence. This interpretation places too strict conditions on the role of the body in cognition.

In the weaker interpretation (perception requires the acquisition of a mastery of sensorimotor contingencies, not necessarily by the actual exercise of this mastery), perception in LIS could be preserved despite the lack of current movement (and similar claims can be made for cognition in general). It suffices that the LIS patient has engaged in sensorimotor interactions and acquired sensorimotor skills at some point before becoming paralyzed. Such reply would amount to a narrow developmental response. It thus escapes the challenge posed by LIS and risks trivializing the role of the body for cognition to mere contingency or historical relevance. In cases of LIS, a weaker interpretation would seem to force us to an intuitive fallback to a cognitivist view on cognition according to which cognitive capacities require no bodily activity.

### 4.2 Negotiating the body in the extended functionalist approach

Extended functionalism is known for the claim that cognition exceeds the brain, body, and organism.[1] The claim about extension of cognition beyond the boundaries of the body already implies an extension of cognition from neuronal processes to *embodied* processes (Clark 2008b). For the proponent of extended functionalism certain bodily processes count as cognitive. Examples in support include cases of mental rotation (Clark and Chalmers 1998) and the epistemic use of gestures (Clark 2008a, pp. 123–127). According to extended functionalism, therefore, the body is part of a larger distributed cognitive system comprising neuronal, bodily and environmental vehicles (Wheeler 2005, 2010; Wilson 2004; Clark 1997, 2008a, b). The body can sometimes adopt the role of easing the computational load arising for solving a cognitive problem by constraining and pre-processing sensorimotor information flows. In contrast to the sensorimotor approach however, this role is considered as explicitly contingent and negotiable. The extended functionalist denies that cognition is necessarily tied to particular bodily structures or processes.

Let us consider our first question—what is the body or what are the distinguishing features of a body? As is the case with the sensorimotor approach we do not find an

[1] In his review of recent approaches to embodiment Gallagher has referred to extended functionalism as "embodied functionalism" (Gallagher 2011). Here we stick to "extended functionalism" since it is the term originally used by Clark.

explicit answer to this question so that, again, we point out indications of what could count as an answer for extended functionalism. Consider the following claims about cognitive extension: "we should (normatively speaking) ignore the old metabolic (sic) boundaries of skin and skull" (Clark 2008a, b, p. 77), "the target behavior seems to be smeared across the biological organism and the world" (ibid. p. 79). The body, which is what is arguably transcended in extended cognition, seems to be that which has to do with metabolism, skin and skull, and sensorimotor systems. It seems safe to say that in the extended functionalist approach the body is equated with the biological organism as a whole, which also includes the brain. Again, this does not rule out that a more specific definition of embodiment could be offered from this perspective in the future. But such definition, though maybe refined, should not contradict that the body in extended functionalism appears to be the individual biological organism.

Let us consider how the extended cognition approach would respond to our second question, i.e. what is a cognitive process? According to Clark, "bodily and worldly elements emerge as genuine parts of extended problem-solving regimes apt for formal description in either (or both) dynamical and information-processing terms" (Clark 2008a, p. 202). Cognition from this perspective is therefore equated with traditional computational information processing and mostly about problem solving. The only difference in this respect with traditional cognitivism is that extended functionalism admits for information processing to take place in parts of the body other than the brain and in extra-organismic processes as well.

What does the extended functionalist say about the relation between the body and cognition? Clark admits that cognition in our world happens to be realized by a body, however its role is not exclusive, but negotiable (Clark 2008a, p.123). The body matters for cognition as part of a "larger mechanism story" (Clark 2008b, p. 39) and "by virtue of the suite of abstract opportunities (encodings, operations) that it makes available" (Clark 2008a, p. 201). If the body is arguably part of the mechanism that realizes problem solving, then we can derive that for extended functionalism a body is cognitive insofar as it can occupy a functional role in realizing a given cognitive process.

The extended functionalist approach thus attempts to place itself at a distance from the sensorimotor approach that assumes "*full-and-principled* sensitivity to all the details of a being's embodiment and/or sensory apparatus" (Clark 2008b, p. 53, original emphasis). As a consequence it appears justified to assume that for the extended functionalist approach even though the body (as organism) *can* play relevant roles in specific instances of cognition, this role is causal and related to providing a useful substrate for information processing to occur. Moreover, some extended functionalist insist that the body is negotiable, only contingently related to its functionality.

How does this conception of the body fare in accounting for the challenge posed by LIS? We see two strategies an extended functionalist could adopt to provide an account of cognition in LIS patients. On the positive side, and in contrast to the sensorimotor approach, the functionalist's liberalism about physiological structures could bring some clarity for understanding the use of BCIs in LIS: According to extended functionalism, human cognition is realized in a three-fold distributed fashion, comprising neuronal, bodily and environmental features. This does not mean that a given cognitive process has to be realized by all three of them. The case of Otto, the Alzheimer patient, illustrates this classically: suffering from Alzheimer, Otto has memory restrictions at the neuronal level. Those restrictions are accommodated by Otto's use of the notebook.

What was a usual component of the functional organization of Otto's mind, i.e. neural structures associated with memory, has been substituted by another component, namely the notebook (an external tool). As long as an extra-neural component meets the parity principle and the criteria of "trust and glue" it counts as part of the cognitive system and thus realizes a cognitive process (Clark and Chalmers 1998; Clark 2008b). A similar story could be given in the context of LIS: BCIs could be seen as a replacement for those parts of the overall "intelligent organization" that have so far been implemented by the body (Clark 2008b, p. 56). The extended functionalist could thus argue that BCI extend the LIS patient's mind (Fenton and Alpert 2008 and Walter 2010; Kyselo 2013a, 2013b). According to this line of reasoning the fact that LIS patients cannot move their bodies would not pose a problem to extended cognition because cognition could be realized by a two-component interplay of brain and BCI. This account would in fact be a good example of what extended functionalists mean by the body being negotiable.

Another, and similar, strategy to account for LIS patients in the classical state from an extended functionalist perspective could be to argue that whatever functional role that the body played in cognition is now realized by an internal "emulator circuitry" in the brain (Clark and Grush 1999, p. 13, Jeannerod 2001) taking over bodily processes to "act as de-coupleable surrogates for specifiable (usually extra-neural) states of affairs" (ibid., p. 8). Again the extended functionalist could thus reply to the challenge by making a claim about bodily substitution. On this emulation account the body's contribution is substituted by neurons emulating motor activities and additionally (in cases of skilful use) by BCIs.

Both strategies thus offer a plausible account of cognition in LIS and BCI. For extended functionalism a body plays a role for cognition in that it counts as a component of a larger computational mechanism. Since this role is replaceable, LIS, a case of bodily paralysis does not pose a problem to extended functionalism. The patient can realize relevant cognitive processes relying on brain and/or BCI technology. However these strategies turn out to work only by abandoning the role for the body, thus becoming effectively disembodied.

There are two important and related reasons for this. With regards to the first strategy, the issue lies not with the claim itself that an artificial component can substitute for a bodily component. The functionalist approach explicitly considers the role of non-physiological structures/processes for cognition. In this aspect, it clearly has an advantage over the restrictions of the sensorimotor approach. However, the theoretical and empirical legwork of specifying *how* BCIs are used cognitively remains to be done. The claim requires a prior determination of criteria for something to count as a substitution[2].

[2] An anonymous reviewer pointed out that the extended functionalist is not restricted to a substitution only strategy. The extended functionalist could argue that given the criteria of "trust and glue" (automatic endorsement, reliability etc.) are met, a tool realizes a cognitive process independent from the question whether or not that same cognitive process is already realized by a brain or body. Accordingly, one could maybe argue that the BCI extends the LIS patient's cognition if the "trust and glue" criteria are met. However, while we agree that there could be a case of an external tool counting as part of cognition, even though it does not substitute a cognitive process—it could for example *augment* a cognitive process —such a story is not suitable for the present context of LIS and BCI usage. BCIs are usually not considered to augment a patient's "normal" cognitive capacities. BCIs are so relevant for the patient precisely because they allow for cognitive processes (such as communication) the patient would be otherwise unable to realize. In other words, BCIs replace a usually otherwise realized capacity. Such a claim entails a claim about substitution and this holds independent from whether the capacity in question was originally bodily or neuronal based.

In a first step this would involve a clarification of the functional role that was previously occupied by the body and is now substituted by the BCI. For making this clarification, it does not suffice to merely state that the BCI plays the same role that the body previously played. The way the claim is framed (as a replacement of one negotiable part by another) implies that the body was never crucial for extended functionalism.

A similar issue arises for a possible argument from emulation. To suggest that the LIS patient can emulate previously available bodily processes is very close to the weak claim of sensorimotor contingencies already discussed above. Both the emulation strategy and the idea that the brain "re-uses" previously acquired knowledge of sensorimotor contingencies are variants of the narrow developmental response that reduces embodiment to a causal-historical factor—bodily activity has been relevant in the past, but now that the patient is immovable, it is no longer needed.

The confrontation of extended functionalism with LIS and BCI thus reveals two worries. Its account of embodiment is too loose, ultimately reflecting a deeply rooted problem, namely the need to clarify the body's role for cognition and a sufficiently specific account of what cognition is in the first place. The other worry is that, in the case of LIS, the account would either prove to be disembodied (no conceivable crucial role due to the body's contemporaneous negotiability) or at best escape into a narrow developmental response offering a causal account of how the body would be required only for the acquisition but not for the disposition or enactment of a cognitive process.

Because of the minor differences with cognitivism with respect to conceptions of the body and cognition, extended functionalism, in so far as we consider it as saying something about embodiment, is too weak to yield any information from the LIS challenge, except that cognition in LIS patients is not a problem if bodily-enabled cognitive skills are in place or susceptible of being replaced by extra-organismic processes.

The question is whether there can be an approach to non-neural embodiment that is more liberal than the sensorimotor approach thus allowing us to account for the role of a non-moving body and of non-physiological structures in cognition but not as loose as the extended functionalist approach that limits the role of the body to that of a replaceable hardware component.

### 4.3 Identity and meaning in the enactive approach

In the enactive approach the body is essential for cognition in the sense that without a world-situated, not merely neural body there can be no cognition. This is a constitutive claim, but it may additionally admit of empirically interesting causal aspects as we shall see. In order to understand this claim we first need to consider what cognition, in the enactive sense, actually is. Two intertwined key notions provide the basic idea: autonomy and sense-making (Di Paolo, et al. 2010; Thompson 2007; Varela 1997). Autonomy is the property of a system that self-produces and strives to maintain its identity as the system that it is. The nature of this identity is conceived of as a dynamic network of precarious processes where each process is enabled by other processes in the network and also contributes to enable other processes in the network (Di Paolo 2009; Di Paolo and Thompson forthcoming). The enactivist calls this identity autonomous because the system is constrained but not fully determined by external factors; instead it follows its own intrinsic norms. Linked to this idea is the notion of sense-making, which refers to a system's ability to regulate its states or interactions with the

world adaptively (Di Paolo 2005; Thompson 2007). This is inextricably linked to autonomy insofar as the regulation happens with respect to the implications for the continuation of the system's autonomous identity. For enactivism a system is *cognitive* when it acts in terms of value or concern with regards to its own existence.

How does the enactivist answer our first question, what is a body? Broadly speaking the enactive body can be associated with the living organism as a whole and to its appropriations of non-organic structures and processes as they are integrated into the autonomous self-sustaining network that makes up its identity. It is a self-individuating, dynamical and precarious unity of organic and non-organic processes that contribute to the conservation of a form of life. It is equated with the "autonomous sensorimotor agent" itself (Thompson 2007, p. 244). In contrast with the sensorimotor and extended functionalist approaches, the body is always seen as an active agent. For the enactive approach the question of embodiment is intimately tied to that of interiority and subjective experience, so that the living organism is not only considered from a mechanistic perspective, i.e. as an entity in the world but also always understood as a centre of subjectivity (Thompson 2007). The enactive body is thus not merely an "objective" body in the German sense of *Körper*, but in line with the phenomenological tradition at the same time also a *Leib*, i.e. a *lived* and experienced body (Merleau-Ponty 2002/1945, p. 106).

Let us now consider the second question—what is a cognitive process? For the enactive approach a cognitive process is *sense-making* as described above, (Di Paolo 2005; Di Paolo et al. 2010; Thompson 2007). Being cognitive is in essence to actively care for a way of existence, which is not guaranteed but constantly at risk of disintegration. Sense-making, which always-already includes affect (Bower and Gallagher 2013), admits for various forms of complexity and styles involving continuous and discontinuous categories, from bacterial chemotaxis to aesthetic judgement (Scarinzi 2012). But at the core, the enactive claim goes, any process that we can describe as cognitive is a case of sense-making. There is no cognitive activity, which is not at the same time an activity that reveals a concernful relation to the world (including oneself and others); thus sense-making is the basic property of all kinds of cognition for the enactivist.

How does enactivism answer our third question, i.e. what is the relation between body and cognition? For this it is important to keep in mind that for the enactive approach the notions of cognitive identity and cognitive process imply each other. According to Thompson we should "understand a lived body as a special kind of autonomous system, one whose sense-making brings forth, enacts, or constitutes a phenomenal world" (Thompson 2007, p. 237), the body is thus the "vehicle of being in the world" (Merleau-Ponty 2002/1945, p.139). Di Paolo and colleagues describe this deep linkage as follows:

> the body is the ultimate source of significance; embodiment means that mind is inherent in the precarious, active, normative, and worldful process of animation, that the body is not a puppet controlled by the brain but a whole animate system with many autonomous layers of self-constitution, self-coordination, and self-organization and varying degrees of openness to the world that create its sense-making activity (Di Paolo et al. 2010, p. 42).

The body is therefore both the means and the end of cognitive activity because it is an autonomous system that makes possible various ways of adaptive regulations of

inner and worldly states that ultimately always refer to the norm imposed by the viability of the body's way of life. For the enactive approach the body as a sense-maker thus always relates to its world in terms of *concern*. Thompson and Varela (2001) specify this in terms of three kinds of embodied processes: self-regulation, sensorimotor coupling, and intersubjective interaction. These forms of regulation are undoubtedly related to one another to the point that the boundaries are not always obvious. But what makes autonomy and sense-making the hallmark of cognitive activity is the naturalization of concern, agency and perspective that these notions allow (Di Paolo 2005; Di Paolo 2009; Di Paolo and Thompson forthcoming; Thompson 2007, 2011). This variety of modes of bodily cognitive activity suggest that while neuro-muscular movement is certainly relevant for some aspects of embodied cognition, it is by no means the only form in which we are embodied. Rather, movement together with self-regulation and intersubjective interaction "constitute us as complex, conscious human beings" (Fingerhut 2012, p. 190).

There are two ways in which a body counts as crucial for cognition in enactivism. First, in the strongest, constitutive, sense, the enactivist makes a general claim about the body's being as that of a self-grounding identity and of a sense-maker (at various levels). The body is a sense-maker by its very nature because the precarious constitution of its autonomous network of constructive processes provides the basic norms for the regulation of interactions with the world, in other words, what the body 'cares about'. In this way, the body is the first grounding of *meaning* or *sense*. If we take meaning or sense as constitutive of cognition, we find then that a body *is* what makes a system cognitive. This, of course, includes the brain in relevant species. But, while neuronal processes count as bodily processes, the function of the brain itself depends on it being enmeshed in a variety of other networks that make up the living body, such as the systems regulating hormone and immune reactions (Cosmelli and Thompson 2010). The brain is "an *organ* of the mind, not its seat" (Fuchs 2011, p. 197). Or to put it differently, the body as a whole, but not its brain, is capable of sense-making. From an enactive perspective, there is no other primary source, which could be driving cognition than the body as a whole.

Secondly, in a causal sense that may be compared with the strong interpretation of the sensorimotor approach, the enactivist makes a claim about the contemporaneous, not merely historical enabling role of bodily processes for sustaining and enacting specific cognitive skills (e.g., spatial reasoning, planning and so on). The body enables the realization of a flexible being in the world. In this, enactivism is very close to pragmatic notions of action. This implies that a body that does not engage with the world, whether by moving itself, or interacting with objects, would in time very likely cease to be the means by which we are in the world as skillful agents. It is very likely the case in general that in order to maintain bodily capacities they need to be regularly put to practice. The enactive body is therefore a *body-in-action*. The enactivist does not limit the role played body in sustaining specific cognitive skills to only a historical role.

On this weaker reading, to say that action (construed already in a wider sense than just movement although the foregoing argument applied to movement too) may be required in order to sustain specific cognitive skills is not to say that the enactment of bodily skills is always and constantly required in the "here and now". To argue that body activity is required either permanently or only historically, thus potentially inviting representationalism, is a false choice that the enactive. Unlike the sensorimotor

approach, seems to avoid because of the stronger constitutive claim that has already been established (i.e., the body is always already sense-maker by its very nature, regardless of how it displays and enacts its various cognitive skills). To illustrate this, we suggest thinking the situation in terms of a nutrient metaphor. Living beings have to feed in order to stay alive. By definition of metabolism, they need nutrients in principle, not contingently[3]. Importantly however, they do not need to eat food all the time. Many living beings have some tolerance to abstain from the act of nutrition, i.e., to stay hungry, for a long time relative to metabolic timescales depending on the species and form of life. Nevertheless they have to feed by their very nature, which is not an incidental fact, but a constitutive one, of metabolic life. The analogy suggests that there exists some middle ground between needing something all the time and instantaneously so or needing it only at one point in the history of development. Nutrition is constitutive of the living system but acts of nutrition are not for this reason causally necessary at every instance of time. And yet, they are causally necessary regularly and without a time-limit, not merely historically. Analogously, the regular (not ongoing, but not merely historical either) enactment of bodily skills may be necessary in order to keep the cognitive skill "alive". The performance of acts of sense-making can thus be relevant beyond the mere historical development of a cognitive skill. Yet, it is not required constantly at every moment. Sense-making, like nutrition, is still constitutive of cognition, regardless of how frequently and in which forms it is enacted.

This idea suggests, as an interesting empirical hypothesis, that skills with a postulated strong bodily component one that might not be only historical and affected by LIS, e.g., skillful spatial reasoning, could be gradually transformed, possibly lost, in LIS after a long time if no relevant activity compensates for them.

How does this perspective on embodiment account for cognition in LIS and interaction with BCI? Generally speaking, to adopt an enactive perspective in the context of global paralysis would predict that patients remain embodied to the extent that they are still an autonomous identity and that they are able to act with concern for the continuity of that identity, through ongoing sense-making processes. But what does this mean?

[3] Nutrition is constitutive of metabolism in the standard biological sense of metabolism as the exchange of material and energy with the environment and their transformation into cellular components and energy. More technically, the enactive approach defines the living process as autopoiesis and the latter as a form of material autonomy (Di Paolo 2005, 2009; Thompson 2007; Di Paolo and Thompson forthcoming). The essence of metabolism is precarious operational closure in the space of molecular transformations, which involves a relation towards energy and material resources with the world. This is in line with Hans Jonas' characterization of the essence of life as metabolism, i.e., as a dynamical form made out of ongoing material flux: "This ontological individual, its very existence at any moment, its duration and its identity in duration is, then, essentially its own function, its own concern, its own continuous achievement. In this process of self-sustained being, the relation of the organism to its material substance is of a double nature: the materials are essential to specifically, accidental individually; it coincides with their actual collection at the instant, but is not bound to any one collection in the succession of instants, "riding" their change like the crest of a wave and bound only to their form of collection which endures as its own feat. Dependent on the availability of materials, it is independent of their sameness as these; its own, functional identity, passingly incorporating theirs, is of a different order. In a word, the organic form stands in a dialectical relation of *needful freedom* to matter", (Jonas 1966, p.80). This relation is of its essence, which is why the nutrient analogy works; the organizational requirements that define the class identity of metabolising systems includes nourishment, while the temporal spread of actual acts of nourishment depends on various material and energy budgeting scenarios according to the species.

In the enactive approach the body as a whole grounds the cognitive system's identity and it enables that identity to engage in sense-making processes for which crucially some kind of activity is necessarily required. The enactivist would thus clearly acknowledge that due to the lack of muscular movement the LIS patient's sense-making is severely restricted. However, while overt sensorimotor activity intuitively may count as the most important type of bodily activity, equating bodily action only with motor movement would be too narrow. In enactivism bodily action (sense-making) comprises more than overt neuro-muscular activity.

First, bodily action must not be limited to *overt* processes, i.e. movement or other behaviorally visible processes. There are *covert* bodily processes, within or of the organism that are not (at least not without additional measurement and methods) accessible from the outside, changing the focus of auditory attention, for instance. Such covert bodily processes can still play a role in contributing to the maintenance of the body as a centre of identity and perspective on the world. A crucial aspect of this involves processes of self-regulation (Thompson and Varela 2001), which does not always rely on neuro-muscular movement. We can assume that self-regulatory activity persists in LIS patients despite severe paralysis. This activity could even count as a non-movement-based skill as Birbaumer et al. have recently proposed with regards to voluntary self-regulation of neuronal activity in BCI use (Birbaumer et al. 2003, 2013). Note thus that the term "covert bodily action" does not refer only to neurobiological processes, as proposed by Hanna and Maiese (2009, p. 102).

But we can also ask to which extent covert bodily processes are involved in world directed cognitive engagements, i.e. in the body as the means of sense-making. The patient is still sensitive to the world and can, for example, hear other people's voices. Since these engagements rely on activity that is partly covert, i.e. not involving muscular movement, they could arguably count as aspects of the interactive body that still subsist despite LIS. Being involved in a particular bodily activity also and already involves certain sensitivity to action possibilities that are not actualized in the same moment. One could argue that any world-directed bodily activity thus also implies some sort of *virtual* bodily activity. Enabling such sensitivity to virtual action possibilities may involve non-muscular covert bodily processes. Consider for example trying to follow different conversations held by people in a crowded place. Shifting attention or tuning in and out to different conversations is a form of sense-making. We regulate our coupling to different aspects of the world, yet without necessarily involving neuro-*muscular* activity. It seems then safe to presume that since these processes persist in a patient with global paralysis that she still is *bodily active* in this sense.

Secondly, we could expand the narrow concept of bodily action as movement asking how *non*-organismic processes can contribute to enabling both embodied autonomy and sense-making. The enactive body is defined in terms of its role for grounding a cognitive identity and allowing that identity to adaptively regulate its states and interaction with the world. For that reason the enactivist would not presume that the boundaries of the body fall together with the boundaries of the organism (Di Paolo 2009). As said above, non-organismic processes can count as bodily if (and only if) they become essential part of the network constituting the cognitive system's identity, i.e. when they are constitutive of the production and maintenance of its autonomy and sense-making capacities.

Unlike extended functionalism, the enactive approach hereby offer an operational condition beyond causal relevance for testing whether extra-organismic processes are constitutive of a cognitive body: whether they belong or not to a self-sustained network of precarious processes that sustain the bodily identity. This condition of *incorporation* provides a route towards accounting for cognition in LIS patients that use BCI. Rather than arguing, along the lines of extended functionalism, that the technology substitutes the body, an enactive approach would propose that if a technological device enables the patient to maintain her identity (in some form) and to engage in sense-making interactions with the world and the way the device is used is reciprocally dependent on the body, then that device has become incorporated. The skillfully used BCI does not substitute the body but becomes part of the patient's body.[4]

By grounding the notion of the body as autonomous identity and sense-making the enactive approach provides a middle way between the restrictive strong sensorimotor perspective and the liberal extended functionalist approach. Embodiment is not limited to movement or particular physiological structures/processes and can therefore involve non-organismic processes. However, in order to account for the incorporation of such elements as tools the enactivist does not trivialize the role of the body. Because the question of embodiment is linked to a specific account of cognition the enactive approach can begin to sensibly explain why and how certain tools can enable actions the patient could otherwise not perform.

The enactive approach does thus not deny that sense-making capacities can be heavily restricted in the LIS patient. For instance, on this view we could speculate that spatial forms for cognition might be more heavily affected than others, such as social understanding. It remains also obvious that the patient's sense of self will be affected (though less severely as may be intuitively assumed, see Nizzi et al. 2012). However, the enactive perspective puts a finger on aspects of embodiment and types of bodily action that may persist in the LIS patient but would be probably overlooked by adopting either a sensorimotor or extended functionalist approach. We begin to understand how organismic and trans-organismic processes integrate to constitute the body as a means of cognitive engagement with the world. But we are also offered a route to understanding the body's role in grounding a cognitive identity and thus for enacting subjectivity and a sense of self. From an enactive perspective a LIS patient is bodily active because embodiment is more than neuro-muscular movement. As long as the

[4] An interesting parallel can be drawn to the work of Merleau-Ponty here. He says that "sometimes, finally, the meaning aimed at cannot be achieved by the body's natural means; it must then build itself an instrument" (Merleau-Ponty 2002/1945, ibid., p. 169). In order to relate to something we usually rely on biological bodily structures, such as our eyes or hands for example. Originally non-bodily objects become appropriated by our habit body and thus cease to exist for us as independent objects. Merleau-Ponty illustrates this famously with the stick of the blind person that allows substituting visual feedback of the person's position with a tactile one. The stick is no longer an external object to the blind person but "has become an area of sensitivity…providing a parallel to sight" (ibid., p. 165). The enactivist might suggest that if our embodied existence can change by "appropriating fresh instruments", then BCI should count as an example of such a non-biological instrument (Merleau-Ponty 2002/1945, p. 166). Having learned how to reliably produce distinct activation patterns to control an artificial limb or a cursor on a screen could be seen as having acquired a new habit. Crucially, BCIs do not extend a pre-existing mind as one might argue from an extended functionalist perspective. Just like the stick for the blind person they are "incorporate[d] into the bulk of our own body". They hence provide an additional structuring element that allows the patient to create a new domain of significance and thus continuously enact her conscious and directed existence in the world (ibid., p. 166).

patient is able to maintain her identity and engage in sense-making activity—however minimal that might be—she will count as embodied.

## 5 Discussion

Let us now take stock and provide a general comparison and evaluation of how the three approaches to embodiment fare in accounting for the challenge posed by LIS and the use of BCI (see Table 1).

The sensorimotor approach appears to make two claims about the role of the body in LIS. It emphasizes the role of contemporaneous neuromuscular movement but also suggests that mastery of sensorimotor skills could be sufficient for perception. This leads to a paradox in assessing the case of LIS. Given the lack of bodily movement the strong sensorimotor approach should predict that patients with LIS could not have perception or perceptual experiences. But, in the weaker interpretation, perception depends on the existence of sensorimotor knowledge, which suggests that LIS patients can in fact have perceptual experiences thanks to neural resources that rely on previously acquired sensorimotor skills. This paradox is still a matter of much debate (Shapiro 2011; Block 2005; Fingerhut 2012) but we have asked what are the independent implications of each of these statements for our problem. We have seen that on the first account the sensorimotor approach is too restrictive because of a limited conception of what counts as embodiment, viz. contemporaneous neuro-muscular movement, which is largely absent or overly restricted in LIS. The second claim then implies a narrow developmental role for the body as it assumes that it matters only in the historical acquisition of a cognitive skill. As a consequence, analyzing each claim separately, the sensorimotor approach cannot meet the challenge posed by LIS in the terms we have proposed. In order to do so it would have to resolve the paradox between

**Table 1** An overview of the concepts of body, cognition and their interrelation in three recent approaches to embodied cognitive science (extended cognition, sensorimotor approach and enactivism), as well as of their assessment in the context of LIS and BCI use

| | Sensorimotor approach | Extended cognition | Enactivism |
|---|---|---|---|
| What is a body? | Organism, neuro-muscular structures | Organism, neuro-muscular structures | An autonomous process of identity and sense-making |
| What counts as a cognitive process | Agent-world coupling | Information processing | Sense-making/ identity maintenance |
| Role of the body | Strong and weak. ambiguous | Contingent, replaceable. Causal | Constitutive |
| LIS assessment | Too restrictive (strong version). too lose (weak version) | Too loose | Adequate |
| Limitations | Limited account of cognition/agency/ subjectivity | Limited account of cognition/ agency/subjectivity | Limited account of embodiment in relation to sociality |

the requirement of ongoing action and the claim about the sufficiency of the mastery of sensorimotor skills.

In contrast, extended functionalism argues that cognition does not necessarily rely on specific bodily structures or movement. In this approach the body is considered a replaceable component of a distributed computational mechanism. It can be either replaced by neuronal states that emulate previously embodied interaction without requiring further actualization, or by a BCI assuming a functional role within a problem solving mechanism.

The problem with this account is that it lacks both a principled definition of body and of cognition, and as well as an account of how they relate, rendering specific claims unfalsifiable as the notions of body and cognition shift conveniently. It remains therefore unclear why and how a technology such as BCI could replace the body or be otherwise integrated into the cognitive architecture and how it would be related to the LIS patient's cognitive life. Extended functionalism defends a notion of the body that is either *not* crucial for cognition or again reduces it at most to having a historical relevance. If the body does not matter for cognition to begin with, then like cognitivism extended functionalism is not immediately affected by the LIS challenge (it may have other problems but unrelated to the role of the body, e.g., like cognitivism, it would still have to provide a concrete functional story, which so far is missing). For this approach, in so far as embodiment is concerned, the challenge does not exist. One might argue that if the dispute was only between a strong sensorimotor approach and extended cognition, then LIS would provide empirical support to abandon an embodied approach to cognition for a functionalist one.

The above conclusion, we emphasize, depends on the readings we make of how these approaches conceive of the body and of cognition in general—these notions, as we have shown, are hardly explicit. Things are different with the enactive approach because, for better or for worse, it makes explicit what it means by cognition. The notions of autonomy (the system's identity) and sense-making (the cognitive process) specify what a body is and how it is related to cognition. In enactivism a) embodiment grounds a system's identity and the normativity of its sense-making and b) bodily action, i.e. sense-making is not equated with neuro-muscular movement, but with all kinds of adaptive regulations of the coupling between agent and world. In the context of LIS and BCI we thus find that although the patient's sense-making capacities are clearly restricted because she cannot move, the patient has other means to realize sense-making and maintain her identity. The enactive approach can acknowledge severe neuro-muscular limitations without having to argue that a LIS patient is disembodied. It offers an account for the skillful use of tools such as BCI but without trivializing the body's role as negotiable. On the contrary, the status of the BCI becomes intelligible because the patient is considered embodied. She is embodied to the extent that she can maintain her identity and engage in sense-making activity. This can involve neuro-muscular processes but is not restricted to them. For enactivism the body matters not only with regards to the acquisition of particular cognitive skills, but continuously, i.e. as long as a person is alive and cognitive.

The enactive approach is thus not unaffected by the challenge (as is extended cognition or the weaker sensorimotor approach) or defeated by it (as is the sensorimotor approach in its strong version). We suggest that the enactive approach, while remaining strongly embodied, rises to the challenge because it offers an integrative notion of

embodiment and thus provides a more thorough assessment of cognition in LIS and BCI than the other two candidates. This does not mean that enactivism has fully resolved the LIS challenge—there are many issues that need to be clarified and for which an enactive account may still prove difficult before a full story can be provided. But it seems that the enactive framework does not have to change fundamentally in order to achieve this. The LIS challenge provides an empirical horizon for the elaboration of an enactive approach to cognition by offering a good starting point and a route towards answering questions such as "what is a sensorimotor skill?", "how is cognitive identity related to bodily action?", "what is the role of experience in the incorporation of tools?" and so forth.

An important aspect—widely neglected throughout the paper, but certainly required by a full account of cognition in LIS and BCI—is the fact that LIS patients are social beings and still embedded in a world of others (Kyselo 2013b). Research on embodied cognition mostly focuses on understanding the individual body in interaction with the material environment yet it widely underestimates the role of sociality. An elaboration of what it means to be a body must consider our social existence and our engagement with other subjects. Again enactivism could serve as a starting point for achieving this elaboration. It has already made promising advances in investigating social understanding (De Jaegher and Di Paolo 2007; De Jaegher et al. 2010; Di Paolo and De Jaegher 2012). But it remains an ongoing research project to further this understanding by investigating the interrelation of social interaction dynamics and the constitution of the individual cognitive identity and embodiment. Reports on their quality of life show that what matters to LIS patients is not so much their physical bodily state or integrity but their relation to other people and that they remain recognized as a person to be engaged with (Bruno et al. 2008; Gosseries et al. 2009; Lulé et al. 2009). If sense-making and autonomy imply each other, as enactivism has it, then this may lead to a view on human cognitive identity as not only embodied, but primarily socially constituted (Kyselo 2013b).

Again, it seems that the case of LIS can be a useful empirical background for testing these ideas. An important aspect of the development of such a proposal will have to be a thorough account of subjectivity (Thompson 2007), a question not considered by the extended cognition and in the sensorimotor approach mainly in terms of particular kinds of (perceptual) experience (Thompson 2005, p. 420).

We have learned above that for enactivism the body is necessarily tied in with subjectivity, it is a centre of experience and grounds a cognitive system's concernful perspective on the world. If embodied cognitive science were to transcend the largely prevalent individualistic perspectives on cognition and consider essential aspects of the human mind to be socially constituted then this may also profoundly affect accounts of subjectivity and sense of self. Such a view might alter our understanding of reports of quality of life in patients with LIS. The fact that LIS patients report no change in their sense of self may depend not so much on the acceptance of physiological impairment, as Nizzi et al. have recently suggested (2012). If the physiological body were considered as the only relevant factor in the constitution of the patients' experienced identity we would miss that it may be because others are still engaging and communicating with them that the patients are actually able to adapt to their situation. Following the enactive approach we may be able to explain why even a dramatic change in bodily possibilities is not always experienced as a rupture of identity. As long as patients are able to engage

in social interaction (communication via BCI, for instance) they ensure the maintenance and negotiation of socially mediated self-constituting processes of identity maintenance. Because of this and regardless of their bodily impairment they experience their identity as largely unaffected, which, in our view, would essentially equate to experiencing themselves as somebody that is both recognized as a distinct individual that at the same time can be addressed and engaged with (Kyselo 2013b). In this way, far from challenging the notion of embodiment, the analysis of LIS evidence from the enactive perspective can be seen as directing embodied cognitive science towards its next development. One important aspect of that could be to elaborate on the relation between types of autonomy, i.e. autonomy as an embodied identity and autonomy as a social person (ibid.). A related question and of general concern for the enactive approach is how the enactive notion of autonomy as cognitive identity (embodied or social) relates to the concept of autonomy as an *ethical* notion. This is an issue relevant for the present context of medicine but also for psychiatry (patient-doctor relation).

Note that while the enactive approach to the body claims to provide a basic notion of human embodiment it does so without presupposing a particular normative stance on what kind of body is involved or whether there exists anything like a "standard body" (Zebrowski 2009). To the contrary, since the body is an autonomous process and its relations with the world define a particular history intertwining biology and social existence, the enactive approach offers a route to address the diversity and multiple dimensions of human embodiment, whether the focus is put on gender, on the incorporation of tools or prostheses, or on how the body is transformed by labor and social inequalities.

Derivations from what may be perceived as a "normal" body, do not have to fall into the category of "disembodied". Here we have shown this for the case of patients with LIS, an extreme case of global paralysis. But the enactive approach might be similarly promising to shed light on other dimensions of embodiment including less severe or other forms of physiological impairment, such as quadriplegia, Moebius syndrome, but maybe also, for instance alterations of bodily self-experience in mental disorders.

## 6 Conclusion

In this paper we have considered LIS as posing a challenge to embodied cognitive science, namely a challenge that demands from embodied cognitive scientists in general to specify the claim that the body plays a crucial role in cognition. We have considered different conceptions of embodiment—the sensorimotor approach, extended functionalism, and enactivism—and examined how they might account for cognition and BCI use in LIS patients. Based on specific questions about the notion and role of embodiment in each case, we have found that the strong sensorimotor conception, with a focus on neuro-muscular activity and instantaneous action is too narrow to accommodate the challenge. The extended functionalist approach in contrast, considers the role of the neuro-muscular activity as contingent and thus offers a potentially useful account of BCI use. However, this approach to the body is too loose—the negotiable status of the body is in tension with the embodied claim that it is crucial for cognition. A weak sensorimotor approach, for the purposes of our problem, very much reduces to the same

perspective. Both the weak sensorimotor and functionalist approaches, as far as the body is concerned, seem to commit to the narrow developmental escape route from the problem, according to which bodily structures are at most historically relevant but do not matter for enactment and disposition of cognitive skills in the here and now.

The enactive body, as an ongoing precarious process of self-construction, is conceived of as grounding cognitive identity and meaning generation. These ongoing processes are not restricted to neuro-muscular activity and can also include covert bodily action. From an enactive perspective the role played by the body in cognition is neither contingent nor merely causal. It is constitutive, firstly, in grounding the very existence of the concernful, cognitive system. Secondly, it is crucial in the development of cognitive skills, but importantly also in its current enactment and disposition. Without the body, in its precarious self-maintaining nature, the world does not make sense since no*body* cares about it, and hence there cannot be any cognition.

On adopting an enactive perspective on embodied cognition, the challenge to LIS can potentially be accounted for in a more refined manner. Global paralysis clearly restricts the patient's sense-making capacities (and this can lead to testable new hypotheses) but this does not mean that the patient is disembodied. A patient is embodied to the extent that she still is a sense-maker, it cannot be otherwise in this view. LIS does therefore not show that embodied cognition is mistaken, it only reveals the degrees to which different approaches are too narrow, too broad or adequate to meet this its challenge. LIS forces us to make explicit our intuitions and be more specific about what we mean by the body and by cognition. We have outlined how on adopting the enactive approach we can begin to address the LIS challenge and we have offered some steps towards a further elaboration of embodied cognitive science as a true alternative to traditional and disembodied approaches to cognition.

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## References

Aizawa, A. (2007). Understanding the embodiment of perception. *The Journal of Philosophy, 4*(1), 5–25.

Albahari, M. (2007). *Analytical Buddhism: The two-tiered Illusion of Self*. New York: Palgrave Macmillan.

Anderson, M. L. (2003). Embodied cognition: a field guide. *Artificial Intelligence, 149*(1), 91–130.

Bauby, J. D. (1997). *The diving bell and the butterfly*. London: Harper Perennial.

Bauer, G., Gerstenbrand, F., & Rumpl, E. (1979). Varieties of locked-in syndrome. *Journal of Neurology, 221*, 77–91.

Birbaumer, N. (2006). Breaking the silence: Brain–computer interfaces (BCI) for communication and motor control. *Psychophysiology 43*, 517–532.

Birbaumer, N., & Cohen, L. G. (2007). Brain–computer interfaces: communication and restoration of movement in paralysis. *Journal of Physiology, 579*(3), 621–636.

Birbaumer, N., Hinterberger, T., Kübler, A., & Neumann, N. (2003). The thought-translation device (TTD): neurobehavioral mechanisms and clinical outcome. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 11*(2), 120–123.

Birbaumer, N., Ruiz, S., & Sitaram, R. (2013). Learned regulation of brain metabolism. *Trends in Cognitive Science, 17*(6), 295–302.

Block, N. (2005). Book review of action in perception. *The Journal of Philosophy, 102*, 259–272.

Bower, M., & Gallagher, S. (2013). Bodily affectivity: Prenoetic elements in enactive perception. *Phenomenology and Mind 4*(1), 78–93

Bruno, M.-A., Pellas, F. & Laureys, S. (2008). Quality of life in locked-in syndrome survivors, *Yearbook of Intensive Care and Emergency Medicine*: 881–890.

Buhrmann, T., Di Paolo, E., & Barandiaran, X. (2013). A dynamical systems account of sensorimotor contingencies. *Frontiers in Psychology*. doi:10.3389/fpsyg.2013.00285.

Clark, A. (1997). *Being there: Putting brain, body and world together again*. Cambridge: MA: MIT Press.

Clark, A. (2008a). *Supersizing the mind: Embodiment, action, and cognitive extension*. Oxford: Oxford University Press.

Clark, A. (2008b). Pressing the flesh: a tension in the study of the embodied, embedded mind? *Philosophy and Phenomenological Research, 76*, 37–59.

Clark, A., & Chalmers, D. (1998). The extended mind. *Analysis, 58*, 7–19.

Clark, A., & Grush, R. (1999). Towards a cognitive robotics. *Adaptive Behavior, 7*(1), 5–16.

Cosmelli, D., & Thompson, E. (2010). Embodiment or envatment? Reflections on the bodily basis of consciousness. In J. Stewart, O. Gapenne, & E. A. Di Paolo (Eds.), *Enaction: Towards a new paradigm for cognitive science* (pp. 361–385). Cambridge: MIT Press.

De Jaegher, H., & Di Paolo, E. (2007). Participatory sensemaking: an enactive approach to social cognition. *Phenomenology and the Cognitive Sciences, 6*(4), 485–507.

De Jaegher, H., Di Paolo, E., & Gallagher, S. (2010). Can social interaction constitute social cognition? *Trends in Cognitive Science, 14*(10), 441–447.

Di Paolo, E. (2009). Extended life. *Topoi, 28*, 9–21.

Di Paolo, E., & De Jaegher, H. (2012). The interactive brain hypothesis. *Frontiers in Human Neuroscience, 6*(163). doi:10.3389/fnhum.2012.00163.

Di Paolo, E., & Thompson, E. (forthcoming). The enactive approach. In L. Shapiro (Ed.), *The Routledge handbook of embodied cognition*. New York: Routledge Press.

Di Paolo, E., Rohde, M., & De Jaegher, H. (2010). Horizons for the enactive mind: Values, social interaction and play. In J. Stewart, O. Gapenne, & E. A. Di Paolo (Eds.), *Enaction: Towards a new paradigm for cognitive science* (pp. 33–87). Cambridge: MIT Press.

Dobkin, B. (2007). Brain-computer interface technology as a tool to augment plasticity and outcomes for neurological rehabilitation. *The Journal of Physiology, 579*, 637–642.

Engel, A., Maye, A., Kurthen, M., & Koenig, P. (2013). Where's the action? The pragmatic turn in cognitive science. *Trends in Cognitive Sciences, 17*(5), 202–209.

Fenton, A., & Alpert, S. (2008). Extending our view on using BCIs for locked-in syndrome. *Neuroethics, 1*, 119–132.

Fingerhut, J. (2012). The body and the experience of presence. In J. Fingerhut & S. Marienberg (Eds.), *Feelings of being alive* (pp. 167–199). Berlin & Boston: Walter De Gruyter.

Fuchs, T. (2011). The brain as a mediating organ. *Journal of Consciousness Studies, 18*(7–8), 196–221.

Gallagher, S. (2006). *How the body shapes the mind*. New York: Oxford University Press.

Gallagher, S. (2011). Interpretations of embodied cognition. In W. Tschacher & C. Bergomi (Eds.), *The implications of embodiment: Cognition and communication* (pp. 59–71). Exeter: Imprint Academic.

Gallese, V. (2010). Embodied simulation and its role in intersubjectivity. In T. Fuchs, H. C. Sattel, & P. Henningsen (Eds.), *The embodied self. Dimensions, coherence and disorders* (pp. 78–92). Stuttgart: Schattauer.

Goldman, A. (2012). A moderate approach to embodied cognitive science. *Review of Philosophy and Psychology, 3*(1), 71–88.

Goldman, A., & Vignemont, F. (2009). Is social cognition embodied? *Trends in Cognitive Sciences, 13*(4), 154–159.

Gosseries, O., Bruno, M. A., Vanhaudenhuyse, A., Laureys, S., & Schnakers, C. (2009). Consciousness in the locked-in syndrome. In S. Laureys & G. Tononi (Eds.), *The neurology of consciousness* (pp. 191–203). Oxford: Elsevier.

Gould, S. J., & Lewontin, R. C. (1979). The spandrels of San Marco and the panglossian paradigm: a critique of the adaptationist programme. *Proceedings of the Royal Society of London. Series B: Biological Sciences, 205*(1161), 581–598.

Hanna, R., & Maiese, M. (2009). *Embodied Minds in Action*. New York: Oxford University Press.

Hutto, D. (2005). Knowing what? Radical vs. conservative enactivism. *Phenomenology and the Cognitive Sciences, 4*, 389–405.

Inci, S., & Özgen, T. (2003). Locked-in syndrome due to metastatic pontomedullary tumor—case report. *Neurologia Medico-Chirurgica, 43*, 497–500.

James, W. (1890). *The principles of psychology, Vol. 1* New York and London: Holt and Macmillan.

Jeannerod, M. (2001). Neural simulation of action: a unifying mechanism for motor cognition. *NeuroImage, 14*(1), 103–109.

Jonas, H. (1966). *The phenomenon of life: Toward a philosophical biology*. Chicago: University of Chicago Press.

Kübler, A., & Birbaumer, N. (2008). Brain-computer interfaces and communication in paralysis: extinction of goal directed thinking in completely paralysed patients? *Clinical Neurophysiology, 119*(11), 2658–2666.

Kyselo, M. (2013a). Locked-in syndrome and BCI – towards an enactive approach to the self. *Neuroethics, 6*, 579–591.

Kyselo, M. (2013b). *From body to self - towards a socially enacted autonomy, with implications for locked-in syndrome and schizophrenia*. Doctoral thesis, University of Osnabrück.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to Western thought*. New York: Basic Books.

Laureys, S., Pella, F., Van Eeckhout, P., Ghorbel, S., Schnakers, C., Perrin, F., Berré, J., Fayonville, M., Pantke, K., Damas, F., Lamy, M., Moonen, G., & Goldman, S. (2005). The locked-in syndrome: what is it like to be conscious but paralyzed and voiceless? *Progress in Brain Research, 150*, 495–511.

Lulé, D., Zickler, C., Häcker, S., Bruno, M. A., Demertzi, A., Pellas, F., Laureys, S., & Kübler, A. (2009). Life can be worth living in locked-in syndrome. *Progress in Brain Research, 177*, 339–351.

Merleau-Ponty (2002/1945). *Phenomenology of perception*. London: Routledge.

Nizzi, M.-C., Demertzi, A., Gosseries, O., Bruno, M.-A., Jouen, F., & Laureys, S. (2012). From armchair to wheelchair: how patients with a locked-in syndrome integrate bodily changes in experienced identity. *Consciousness and Cognition, 21*(1), 431–437.

Noë, A. (2004). *Action in perception*. Cambridge: MIT press.

Núñez, R. (2004). Do real numbers really move? Language, thought, and gesture: The embodied cognitive foundations of mathematics. In F. Iida, R. Pfeifer, L. Steels, & Y. Kuniyoshi (Eds.), *Embodied artificial intelligence* (pp. 54–73). Berlin Heidelberg: Springer.

O'Regan, K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences, 24*, 939–1031.

Plum, F., & Posner, J. B. (1966). *The diagnosis of stupor and coma*. Philadelphia: F. A. Davis.

Reddy, V. (2003). On being the object of attention: implications for self-other consciousness. *Trends in Cognitive Sciences, 7*(9), 397–402.

Roberts, T. (2009). Understanding 'sensorimotor understanding'. *Phenomenology and the Cognitive Sciences, 9*, 101–111. doi:10.1007/s11097-009-9125-7.

Rohrer, T. (2007). The body in space: Dimensions of embodiment. In T. Ziemke, J. Zlatev, & M. F. Roslyn (Eds.), *Body, language and mind 1. Embodiment* (pp. 339–377). Berlin/New York: Mouton de Gruyter.

Scarinzi, A. (2012). Grounding aesthetic preference in the bodily conditions of meaning constitution. *The Nordic Journal of Aesthetics, 43*, 83–104.

Schnakers, C., Majerus, S., Goldman, S., Boly, M., Van Eackhout, P., Gay, S., Pellas, F., Bartsch, V., Peigneux, P., Moonen, G., & Laureys, S. (2008). Cognitive function in the locked-in syndrome. *Journal of Neurology, 255*, 323–330.

Shapiro, L. (2011). *Embodied cognition*. New York: Routledge.

Shapiro, L. (forthcoming). When is cognition embodied? In U. Kriegel (Ed.), *Current controversies in philosophy of mind*. New York: Routledge.

Thompson, E. (2005). Sensorimotor subjectivity and the enactive approach to experience. *Phenomenology and the Cognitive Sciences, 4*, 407–427.

Thompson, E. (2007). *Mind in life: Biology, phenomenology, and the sciences of mind*. Cambridge: Harvard University Press.

Thompson, E. (2011). Précis of *Mind in life*. *Journal of Consciousness Studies, 18*, 10–22.

Thompson, E., & Varela, F. (2001). *The embodied mind: Cognitive science and human experience*. Cambridge: MIT Press.

van León-Carrión, J., Eeckhout, P., & Dominguez-Morales, M. R. (2002). The locked-in syndrome: a syndrome looking for a therapy. *Brain Injury, 16*, 555–569.

Varela, F. J. (1997). Patterns of life: intertwining identity and cognition. *Brain and Cognition, 34*, 72–87.

Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind*. Cambridge: MA: MIT Press.

Walter, S. (2010). Locked-in syndrome, BCI, and a confusion about embodied, embedded, extended, and enacted cognition. *Neuroethics, 1*, 61–72.

Wheeler, M. (2005). *Reconstructing the cognitive world: The next step*. Cambridge: MIT Press.

Wheeler, M. (2010). In defense of extended functionalism. In R. Menary (Ed.), *The extended mind*. Cambridge: MIT Press.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625–636.

Wilson, R. A. (2004). *Boundaries of the mind: The individual in the fragile sciences: Cognition*. Cambridge: Cambridge University Press.

Wolpaw, J. (2007). Brain–computer interfaces as new brain output pathways. *Journal of Physiology, 579*(3), 613–619.

Zahavi, D. (2005). *Subjectivity and selfhood: Investigating the first-person perspective*. Cambridge: MIT Press.

Zebrowski, R. L. (2009). *We are plastic: Human variability and myth of the standard body*. Doctoral thesis. University of Oregon: Eugene, Oregon.

Ziemke, T. (2003). *What's that thing called embodiment? Proceedings of the 25th Annual Meeting of the Cognitive Science Society* (pp. 1305–1310). Hillsdale: Lawrence Erlbaum.