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Bodily structure and body representation

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Abstract
This paper is concerned with representational explanations of how one experiences and acts with one's body as an integrated whole. On the standard view, accounts of bodily experience and action must posit a corresponding representational structure: a representation of the body as an integrated whole. The aim of this paper is to show why we should instead favour the minimal view: given the nature of the body, and representation of its parts, accounts of the structure of bodily experience and action need not appeal to a representation of the body as an integrated whole. The argument proceeds by distinguishing two kinds of explanatory roles for representations: standing-in for absent targets and structuring ambiguous sensory information concerning a target. Representations of body-parts are suited to fulfil both kinds of explanatory role, whereas a representation of the body as an integrated whole is only suited to fulfil the latter, as a means of coordinating representations of body-parts. It is then argued that the structure of the body can itself serve as a means of coordinating body-part representations, rendering representation of the body as an integrated whole explanatorily superfluous.

Keywords Mental representation · Anti-representationalism · Body representation · Body schema · Body image · Structural properties · Bodily sensation · Proprioception · Action · Phantom limb

1 Introduction

Try touching your nose, whilst touching your toes. You may notice that the body-parts you touch (and those *with which* you touch) are experienced as parts of a greater, integrated whole. And the integration of those parts—their structural interlocking—is what makes such a task difficult for all but the most limber. This paper is concerned with representational explanations of how one experiences and acts with one's body in this way,

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not merely as a collection of parts, but as a structure: as an integrated whole. On what I will call the standard view (Sect. 2), accounts of bodily experience and action must posit a corresponding representational structure: a representation of the body as an integrated whole (de Vignemont 2018; Metzinger 2003; O'Shaughnessy 1980/2008). The aim of this paper is to show why this is not so. Given the nature of the body itself and representation of its parts, positing a representation of the body as an integrated whole is explanatorily superfluous—or, so I will argue.

My strategy (outlined in Sect. 3) will be to determine the explanatory utility of positing body representations against the more general background of scepticism about representation. Entertaining such scepticism is particularly apposite when considering the unique nature of the body as a putative object of mental representation. It is the only object which is never wholly absent, the only object for which we possess dedicated (proprioceptive) sensory organs located within the object sensed, and thus, the only object we can sense from the inside. Even when sensing the *world* through sight, sound and touch, the sheer amount of information that we receive concerning the *body* through these channels far outstrips the information concerning anything else. It is also the only object immediately subject to our will. Consequently, whenever we attempt to effect change in other objects, whether we are successful or not, we receive further education about the particular body through which the attempt was made.

Considerations like these can be put to constructive use, to press a theorist to make explicit how each body representation she posits is poised to fulfil a certain explanatory role. In this vein, I argue (in Sect. 4) that representations of body-parts and representation of the body as an integrated whole differ in their explanatory roles. Representations of body-parts are well-suited to serve as stand-ins for their targets and to structure incoming information concerning their targets. By contrast, a representation of the body as an integrated whole is well-suited to coordinating representations of body-parts, in accordance with the structure of the body itself.

I surmise (in Sect. 5) that the most compelling argument for the standard view is that the structure of bodily experience and action requires co-ordination of body-part representations, and that this can only be achieved by encoding the body's structure in a representation of the body as an integrated whole. However, I will argue that this latter claim is false and that the standard view ought to be abandoned, in favour of what I call the minimal view, according to which the structure of the body itself can serve to coordinate representations of body-parts.

Before concluding, I show (in Sect. 6) why various forms of empirical evidence often mustered in favour of the standard view—concerning full-body illusions, innate representations, and body identity integrity disorder—in fact fail to provide any decisive support.

2 Body representation and the standard view

The notion of body representation has a rich, though relatively recent history, much of which is characterised by terminological confusion. The two most commonly used terms in the literature are *body image* and *body schema*, inherited from the writings of late 19th and early 20th century neurologists such as Bonnier (1905), Schilder (1935) and Head and Holmes (1911–1912), and the phenomenologist Merleau-Ponty (1962/2002). These terms are sometimes used interchangeably in discussions of bodily experience and action, without much concern for their distinction (Berlucchi and Aglioti 1997, 2010). Shaun Gallagher (1986, 2005) helpfully suggests that we fix the reference of the *body schema* to the unconscious sensorimotor processes that enable bodily action, using the *body image* as a blanket term to refer to every other internal state that takes the body as its object, including, and especially, conscious experience of the body. Yet, notwithstanding its attractive simplicity, this strictly bipartite distinction is clearly against broader terminological practice (see de Vignemont 2010).

Thankfully, the present discussion need not be hampered by the variety and controversy in the use of notions of body representation. For all said notions may be taken to involve either representation of body parts or representation of the body as an integrated whole.[1] It is this basic distinction that will be our focus—the distinction between representing part(s) of the body and representing the body as an integrated whole. It is a welcome outcome that such a focus allows us to abrogate ourselves of any attempt to clear the terminological minefield. But the real motivation for employing the distinction is dialectical. For there is a broad consensus that something like the following claim is true:

> **The standard view**: An explanation of the structure of bodily experience and/or bodily action, must posit a representation of the body as an integrated whole.

Claims endorsing at least one of the disjuncts, and often the conjunction, have been made explicitly in philosophical accounts of bodily experience and its relation to bodily action (de Vignemont 2018, p. 85 ff.; Lara 2018, pp. 18–20; Metzinger 2015, pp. 273–274; O'Shaughnessy 1980/2008, pp. 264–265 ff.; 1995, pp. 192–194). Similar claims have also been made explicitly, but for largely instrumental purposes, in discussions of the unity of consciousness and self-consciousness (Bayne 2010, pp. 251–252; Metzinger 2003, Ch. 6; Tye 2003, pp. 43–49).[2]

To see why anyone might tempted by the standard view, we need to look at the kind of structure to which it refers. Whilst there are various ways of conceiving of the bodily structure of creatures like us, the structure of interest here is what Casati and Varzi (1999) refer to as a *mereotopological* structure—a whole composed of interlocked parts. As an integrated whole, body parts are interlocked, bearing a mutually constraining connection to one another. These parts are thus experienced

[1] It should be noted that this distinction is also orthogonal to the short-term versus long-term distinction made by some (following O'Shaughnessy 1980/2008) to contrast kinds of represented spatial properties by their temporal variability.

[2] The standard view is also assumed by neuroscientists (Berlucchi and Aglioti 1997, p. 560; Blanke 2012, p. 557; Brecht 2017, p. 991; Melzack 1990, p. 91; Petkova et al. 2011, p. 4; Serino et al. 2015, p. 11), and philosophers and neuroscientists in collaboration (Blanke and Metzinger 2009, p. 7 ff.; de Vignemont et al. 2006, p. 148). Though, of course, the degree to which non-philosophical authors are committed to what philosophers consider a viable notion of a representation is notoriously unclear.

as parts of a greater whole and constrain bodily movement due to the nature of their connection.

To unpack these general remarks in a little more detail, take bodily experience first. Experiences of bodily sensations such as pain, pressure, itch, flutter, etc., typically involve a complex of qualitative and spatial properties (Armstrong 1962; Pitcher 1970). In experiencing a sensation, one experiences both the quality of the sensation and its apparent location in a body-part (Brewer 1995; Martin 1995; O'Shaughnessy 1980/2008, Ch. 5). The body-parts in which one experiences sensations are not experienced in isolation—they are experienced as parts of an integrated whole. Thus, bodily sensations are organised according to a part-whole structure: to the extent that the experience presents any determinate location at all, it presents a location within a body-part; yet all an individual's bodily experiences seem to be experiences of the same body, in so far as each part is experienced as part of an integrated whole.[3]

We can bring the point out by considering how different our experience would be if it did not have this structure. We can try and imagine the experience of a creature, call her *Scatty*, who experiences her body as a disintegrated whole. Her body-parts, as she experiences them, do not form a whole in the same sense that we would say the front and back of a sphere form a whole (Madden 2015). Rather, *Scatty* experiences her body-parts as parts of the same whole in a sense more akin to saying that the top and bottom of a bikini are part of the same bikini. In short, *Scatty* experiences her body as a scattered material object (Cartwright 1975). I suspect that many will find such a case difficult to conceive, because they cannot imagine a subject experiencing a disconnected collection of objects as parts of the same body (cf. Bayne 2010, pp. 264–266). But such a difficulty just serves to illustrate the contrast with the normal case. We do not experience parts of our body as disconnected; we experience them as connected with one another, as parts of an integrated whole.

The body also figures as an integrated whole in bodily actions. Imagine that *Scatty's* body consists only of two detached hands capable of independent movement. She would be like *The Adamms Family* character, *Thing*, but in duplicate. There are many things that she would able to do that normally embodied subjects could not. *Scatty* could rotate each hand three hundred and sixty degrees about its thumb—an action which I trust none of my readers will attempt for fear of injury. She could grasp an elephant's trunk and its tail simultaneously—to do the same, any humanoid would have to be roughly four times larger than the average human (Bassey 1986). Again, the contrast here is intended to show that in the normal case, bodily actions are spatiotemporally constrained by the body itself as a unity of parts. This relationship is made intelligible by conceiving of bodily structure

3 See also the discussion of *boundedness* and *connectedness* in Bermúdez (2017, pp. 124–128). I should note that whilst Bermúdez has done more than most to illustrate the phenomena which would form the explanandum for the standard view, it is not at all clear whether his accounts of these require the notion of an integrated representation of the body (see Bermúdez 1998, Ch. 6; 2005). Bermúdez is not unique in this regard, rather it is typical of theoretical discussion concerning body representation that notion of a representation of body as an integrated whole is often, at best, implicit. Suffice to say that if theorists are tempted to endorse such a notion, I hope that my arguments will rid them of that temptation.

in a way that highlights the constraints it imposes on bodily movement (Bicchi and 2011). For agents whose bodies form an integrated whole, movement of any body-part will take as long as it does, and involve what physical displacements it does, because that part is a part of an integrated whole (Latash 2008b).

It will be assumed, then, that bodily experience and bodily action have a common structure, in so far as our characterisation of them must involve the body *both* in its parts *and* as an integrated whole. It is precisely this structure which a representation of the body as an integrated whole is typically posited to explain.

I should note, however, that the standard view leaves open alternative ways of conceiving of the representational architecture underlying bodily experience and bodily action. For it is not clear that they must involve the same kind of structure in the very same way. For instance, one might think that the interlocking of body-parts figures in the content of representations constraining bodily experience, but not those enabling bodily action. On such a view the interlocking of body-parts figures in bodily action, *only* in so far as the actual unfolding of bodily action consists in body-parts mutually constraining one another. Alternatively, one might deny that the interlocking of body-parts figures in the content of representations underlying conscious experience of the body, but yet affirm that such contents are required for skilful bodily action.

Such bifurcated accounts are worth exploring. But I will not do so here. My focus, rather, will be with the typical expression of the standard view, according to which both bodily experience and bodily action require an integrated representation of the body as a whole. To take a prime example, in her recent book, Frédérique de Vignemont follows a thread that runs through the theoretical work of neurologists and neuroscientists from Bonnier (1905) to Brecht (2017) to develop the notion of a *body map*, a representation of the body which "represents the structural organization of the various segments of the body" (2018, p. 87). The notion of a *body map* builds upon O'Shaughnessy's notion of a *long-term body image*, a representation of the body that serves as a "principle of possibility" for the configuration of those body parts that are the direct objects of bodily experience and means for action (1980/2008, p. 278). Similarly, de Vignemont claims that it is "thanks to the body map that sensations are experienced as being at more than an isolated body point" (2018, p. 85), that in bodily action "sets of body parts […] work together in movements", and that this requires "an integrative representation of the body that brings effectors together" (2018, p. 161).

Thus, according to the standard view, it is not sufficient to appeal to representations of body parts in explaining the structure of bodily experience and bodily action. What is further required is a representation of the body as an integrated whole (e.g. a *body map*, or *long-term body image*). For this explains how it is that representations of parts of the body are coordinated, such that they reflect the integrated structure of the body as it figures in bodily experience and bodily action.

The principal aim of this paper is to show that we ought to reject the standard view, in favour of the following:

The minimal view: Given the nature of the body itself and representation of its parts, an explanation of the structure of bodily experience and/or action need not appeal to a representation of the body as an integrated whole.

The central contention here concerns whether explanations of the structure of bodily experience and bodily action require us to posit a certain kind of representation. My suspicion is that the standard view has become so, in part because no one has yet undertaken the task of analysing the notion of body representation whilst genuinely entertaining the possibility that representations of the body as an integrated whole might not exist.[4] In the next section, I will briefly draw out a methodological framework for addressing such scepticism, before taking up the task of analysing the notion of body representation in adherence to that framework in the section following.

3 Representationalism and its dissent

3.1 Scepticism about representation, and the modesty constraint

The term ‘representational explanation’ or ‘representationalism’ in the current context describes any explanation that involves representations as an explanatory posit, where ‘representation’ is broadly understood as either a content-bearing state or process of the central nervous system, or a content-bearing state or process that supervenes on the central nervous system. Representationalism is dominant in contemporary psychology and neuroscience, and in much philosophy of mind and cognitive science. But a key strand of dissent comprises the view often known as ‘anti-representationalism’ namely that explanations of mental phenomena that posit representations at all might be (or indeed, are) mistaken (Chemero 2009; see also Clark 1997; Ramsey 2007; and Van Gelder 1995 for useful discussion).

I believe it is most useful to frame the very possibility of anti-representationalism as a form of scepticism over the explanatory utility of representational explanations.[5] This imposes what I will call a *modesty constraint* on positing representations, forcing one to consider, on a case by case basis, whether it is possible to explain the phenomena in question without appeal to representations (Grush 2003, pp. 65–66; Van Gelder 1995, p. 352). This axiological constraint is a species of the general value of parsimony. It dictates that caution against positing superfluous representations is a theoretical virtue.

[4] Indeed, with the exception of Gadsby and Williams (2018), theorists in this literature (such as Bermúdez 2005; de Vignemont 2018; Metzinger 2003; and O’Shaughnessy 1980/2008) have not provided arguments specifically designed to show that ‘body representations’ do indeed meet standard criteria for representations—let alone representations of the body as an integrated whole, which also go unmentioned in Gadsby and Williams’ (2018) discussion.

[5] See also the discussion of metaphysical and epistemological anti-representationalist claims in Chemero (2009, pp. 67–68).

The modesty constraint especially has force where there are viable alternatives to representational explanation as the best form of explanation of the phenomenon in question. These alternatives need not rule out representations *tout court*; rather they can be explanations that are *partly non-representational*, in that they give a significant explanatory role to entities that are not representations (Clark 1997, Ch. 8). Indeed, in later sections, I will argue that the body itself, as an integrated whole, can serve a significant explanatory role in an account of the structure of bodily experience and bodily action.

The way to address scepticism about the utility of representational explanations is to make clear, for those representations we do posit, what explanatory role they serve *as representations*. The challenge of specifying such a role for a given theory is what Ramsey (2007, p. xv, ff.) refers to as the "job-description challenge". To meet this challenge would be to do more than merely give an account of how a given state or process might represent some content. For the sceptic can merely deny that there is any explanatory payoff to appealing to a representation carrying such content, provided that the very same phenomena can be explained without such an appeal (Ramsey 1997). Rather, to meet the sceptical challenge would be to clearly specify an explanatory role a putative representation would be well-suited to serve, in virtue of its content.

3.2 Explanatory roles for representations

So, what explanatory roles might a representation serve? Haugeland makes some suggestive remarks in his influential discussion of criteria for representation:

> If [a set of] relevant features are reliably present and manifest to the system (via some signal) whenever [behavioral] adjustments must be made, then they need not be represented [...] But if the relevant features are not always present (manifest), then they can, at least in some cases, be represented; that is, something else can stand in for them, with the power to guide behavior in their stead. (Haugeland 1998, p. 172)

The most obvious explanatory role to be extracted from these remarks concerns the role of serving as something that can "stand in" for some entity that is not "reliably present" to a system through a maintained sensory signal. This certainly has an intuitive pull, as evidenced by the fact that critics of representational explanation have argued that positing representations in cases where there is ongoing sensory contact with that which is purportedly represented is superfluous and dogmatic (Beer 2000; Brooks 1991). Presumably, to do so would be superfluous and dogmatic on the assumption that nothing needs to serve the explanatory role of being a stand-in.

Representationalists have responded to this kind of argument in two very different ways. One way has been to show that cases of ongoing sensory contact in fact involve temporal delays due to physiological constraints in axonal conduction velocity (Grush 1997). But yet, despite these delays, we are able to respond to properties for which signals have not yet been received (see e.g. Desmurget and Grafton 2000). Thus, the argument continues, despite ongoing sensory contact, the cognitive system requires a stand-into manage the ongoing temporal absence of its target (Grush 2003, see also Sect. 4.4 below). This in turn might be the basis for cognitive processes such as planning and imagination, in so far as these can also concern distant objects, properties and events that are absent in a spatial sense (Clark and Grush 1999; Grush 2004). Accordingly, this line of response rests heavily on the explanatory role of representations as stand-ins, where representations are required for cognising about that which is spatially or temporally absent.

Another, very different line of response has been to draw, instead, on the notion of something that is not "manifest" to the system through sensory signals. Here the rejoinder to the claim that representations are not required where sensory contact obtains is that an individual's response may nevertheless be underdetermined by available sensory signals (Clark and Toribio 1994). Consider, for instance, Fodor and Pylyshyn's influential critique of Gibson's (1979/1986) anti-representational account of visual perception. They argue that our immediate sensory input specifies only certain properties of the ambient light, not the environment we perceive. On the 'establishment' view they espouse, information about the environment—even if such information is contained within the structure of the light—must be specified through construction and manipulation of internal representations (Fodor and Pylyshyn 1981).

Clark and Thornton (1997) offer a useful generalisation of the kinds of case which motivate such a theoretical approach. They distinguish between what they call "type-1" problems in which a system can find a direct mapping from input to output can through statistical means and "type-2" problems in which there is no direct mapping available because the input is highly complex and ambiguous. One way of managing problems of the latter type is to learn abstractions which allow future deployment of generalisations—what Karmiloff-Smith (1992) called "representational re-descriptions"—to reduce the complexity of the computations involved in processing current inputs. In Clark and Thornton's (1997) view, in so far as cognitive tasks involve type-2 problems, they warrant positing representations as a means of trading-off computational resources for computational power (see also Klein, forthcoming).

It is worth stressing that this second kind of explanatory role does not involve absence in anything but a metaphorical sense. The representationalist line of response here does not involve claiming that that which is represented is at any spatial or temporal remove from the cognitive system. Rather, the explanatory role is that of structuring the information carried by an "unruly" sensory signal to reflect—make manifest—the structure of some entity (Clark 1997, pp. 145–146, 167–168).

Let us label *standing-in* as the explanatory role motivated by the apparent availability of some entity despite the privation of sensory contact with that entity. This is a natural reading of what it is to stand in for something: to serve in place of something that is (notably) absent.

We can use the term *structuring* for the other explanatory role, motivated by the apparent availability of the structure of some entity, despite that structure not being directly conveyed by the bare sensory signal.

These explanatory roles could do with further refinement for the specific case of body representation (for which see Sects. 4.1–4.2). But for the moment, it is worth noting that each is well-suited to being served by representations with appropriate content. So much so, perhaps, that it might seem that admitting them amounts to begging the question against the sceptic.

On the contrary. Considering explanatory roles for representations can serve as a useful framework for evaluating representational explanations on sceptical grounds, provided that it is assumed that there is nothing in these explanatory roles per se that presupposes they *must* be fulfilled by representations. For this leaves open the possibility of an alternative account in which the same explanatory role is fulfilled by a non-representational entity or process. If such an alternative account can be provided, then, given the modesty constraint, it ought to be favoured.

My argument in the rest of the paper will be framed accordingly. I will argue that representations of body-parts fit both explanatory roles. They can serve as stand-ins for absent body-parts and they can structure the influx of information concerning body-parts. By contrast, a representation of the body as an integrated whole is only well-suited to serve a structuring role. I will then argue that—given representations of body parts—the body itself can serve the very same explanatory role as a representation of the body as an integrated whole, obviating the need to posit such a representation.

4 Explanatory roles for body representations

4.1 Body representations as models

Wilder Penfield's documentation of the associations between direct neural stimulation and bodily sensations revealed a map of body-parts in the brain (Penfield and Rasmussen 1950). This coarse-grained, distorted map of the body in the brain came to be known as the 'homunculus'. It is perhaps the most famous of its kind; though others have proposed more elaborate body maps, both before (e.g. Head and Holmes 1911–1912) and since (e.g. de Vignemont 2018), on more theoretical grounds. The most notable feature of maps *qua* representational structures is that they resemble those things of which they are a map. And the relevant form of resemblance here is not that of simply sharing just any kind of property with another object.[6] Rather the resemblance is that of sharing structural properties, where the relations forming a given structure are mirrored by the relations forming another (O'Brien and Opie 2004; Ramsey 2007, pp. 77–92; Swoyer 1991).

The homunculus is a poor structural representation, as it exhibits such striking distortions: the hands are next to the face, the feet next to the genitals, the thumb is over twice the size of the thigh, etc. Given that we do not experience our bodies as having this kind of shape and organisation, and given that we are perfectly

[6] See Cummins (1989, pp. 27–34) for a discussion of why unconstrained resemblance is implausible as the basis for any general account of representation.

capable of coordinated movement, it is generally assumed that these primary cortical areas feed information into structures that generate more accurate representations of the body, often described as models (de Vignemont et al. 2006, p. 148; Haggard and Wolpert 2005, p. 261; Metzinger 2015, p. 273).[7] Models, like maps, can be used as structural representations. Again, this is in virtue of resemblance between structures, viz. the relations between elements of a model and the relations between parts of another object (Gładziejewski 2016; Johnson-Laird 1983; Swoyer 1991, pp. 488–490).

In the rest of the treatment, I will assume that body representations are best construed as models which are able to represent their targets in virtue of their resemblance to the structure of their targets. This is a framework assumption, required principally for the purpose of establishing common ground between competing accounts —the minimal view and the standard view. But before moving on, I will clarify this approach on several points.

Firstly, a reader might gain the impression from the recurrence of the term 'structure' that structural representation is only suited to serve the explanatory role we have labelled as *structuring*. But on a moment's reflection we can see that this is surely not the case. When an engineer employs a numerical system in reasoning about the viability of an absent target—such as the form of a bridge which is yet to be built—her success in this task is naturally explained by her use of a system of structural representation as a stand-in (cf. Swoyer 1991, pp. 460–463). Similarly, by using structural representations the brain "can silently contemplate, dream, plan, all as a matter of the play of representations—pretty much everything Descartes thought the mind could do in the absence of the world", as Grush rather polemically puts it (2003, p. 87).

Secondly, whilst many theorists use the term *body model*, it should be noted that some theorists opt for the term *body map,* such as de Vignemont in her recent (2018) treatment (see also O'Shaughnessy 1980/2008, pp. 266–267). Maps represent in virtue of the *spatial* relations between their elements, whereas there is no constraint of this kind on models (Gładziejewski 2016, p. 560). I think that the most robust form of the standard view ought to have the liberty to appeal to a variety of relations that might serve as representational vehicles, accordingly I will adopt the more general notion of a model as my idiom.

Thirdly, my aim is not to establish beyond doubt that body representations are models. For instance, it might turn out that our best account of representation of the body involves a symbolic scheme which does not exploit shared structural properties in order to represent its target.[8] Though that strikes me as implausible for the purposes of accounts of bodily experience and bodily action, I do believe the general point is valid.[9] But I cannot hope to address every possible version of the view.

[7] Thanks to a reviewer for pointing out that this assumption is rarely considered in much detail. For more on this point, see note 10 below.

[8] I am grateful to two anonymous reviewers for noting this point.

[9] It is, of course, rather more plausible for accounts of what figures in an individual's understanding of the concept HUMAN BODY. But that is beyond the scope of the present discussion.

Suffice to say that if a proponent of the standard view were to adopt a very different notion of representation to the one proposed in the present treatment, that would affect the dispute substantially.[10]

Fourthly, a famous objection to accounts of representation based upon resemblance is that resemblance is too cheap a relation to serve as an appropriate ground for representation (e.g. Goodman 1969, p. 4). Raising the objection here: it might be said that the relations between elements of a model might resemble the relations between elements of any of a great variety of objects. If the model is held to be a representation of one of these objects in virtue of its resemblance, by the same lights it may just as well be a representation of any of the others. But such indeterminacy in what the model represents in virtue of its resemblance seems like a good reason to reject the claim that it represents anything at all.

There are many things to say about an objection of this kind.[11] For the present purposes, the key response is to note that it only gains force by conceiving of representations in abstraction from their explanatory role. A representation fulfils an explanatory role not just on the assumption that it could represent some object for some unspecified purpose, but rather on the assumption that it could represent some object for some specific purpose. It is a mistake to treat representations in abstraction from their fulfilling an explanatory role in this regard.

4.2 Explanatory roles for body representations as models

In Sect. 3.2, I outlined two kinds of explanatory role representations might fulfil. Representations might serve the role of *standing-in* for an absent target, or they might serve the role of *structuring* incoming information to make manifest the structure within it. In the rest of this section, I will show how models of body-parts can fulfil each of these explanatory roles. They contrast with models of the body as an integrated whole in this respect. For, as I will argue, a model of the body as an integrated whole is only well-suited to the role of *structuring* information. This will be addressed in the next section, where I will also show how appeal to such a representation is the key to a strong case for the standard view.

[10] In addition, I would note that psychologists and neuroscientists working in this area do not typically care about whether, and, if so, *how* some central process of interest ought to be thought of as a representation. Rather, what they care about is whether causally intervening upon that thing's activity affords manipulation of behaviour, and does so in a systematic fashion that reveals something about the role of that thing in generating a particular phenomenon (see e.g. Romo et al. 1998). Thus it might be plausible to say that, notwithstanding incidental use of terms such as 'model', many researchers in this area are not committed a structural notion of representation—what Ramsey (2007) calls 'S-representation'—rather, they are committed to what Ramsey calls a 'receptor' notion of representation. This latter notion is motivated by the fact that anything sufficiently reliably correlated with (or indeed, nomically dependent upon) a specific cause can serve to represent that cause (Dretske 1981, pp. 63–82). But for many who operate with that notion, the distinction between representation and causal relay may be one without a difference, raising the question of whether the former notion is really doing explanatory work that could not be achieved in terms of the latter (Ramsey 2007, p. 142). See also Morgan (2014) for discussion.

[11] For discussion of more sophisticated forms of this objection, and responses, see Shea (2014, pp. 132–136) and Ramsey (2007, pp. 93–96).

4.2.1 Body-part models stand-in for absent body parts

Doubt about the explanatory utility of representations is sometimes expressed by arguing that the information that they would make available as stand-ins is readily available through sensory channels. Kinsbourne expresses a similar line of thought with respect to the body:

> The brain has a readily available repository of information […] an 'outside memory,' like a handy reference library, in the body. The brain can sample this database as needed, rather than internalizing all the body information all the time, just in case some part of it becomes relevant. (Kinsbourne 2002, p. 23)

Perhaps an obvious response on the part of the representationalist is to point to cases in which "one can experience sensations in the complete absence of somatosensory input" (de Vignemont 2018, p. 85). Notably, amputees often suffer hallucinations in which they continue to (often painfully) experience the body-part in question, a phenomenon known as 'phantom limb' syndrome (Finger and Hustwit 2003; Giummarra et al. 2007; Ramachandran and Hirstein 1998). Here the persistence of experience of a body-part, despite loss of sensory contact between the brain and sensors in the relevant peripheral body-part, forces one to conclude the experience must be enabled by a persisting neural process. With respect to this kind of phenomenon, neural representations of the body have a plausible explanatory role: a neural process is employed *as a representation* of the body-part, *standing-in* for that body-part in its absence. By positing such a representation, one might then explain, e.g. how it is that one experiences that part despite its absence.

But as things stand this line of argument is somewhat limited. If the *only* cases in which a representation could fulfil the role of *standing-in* were cases of "complete absence of somatosensory input", such an extreme notion of absence would, absurdly perhaps, restrict any account that posits representations of the body to cases of amputation. It seems unlikely that the nervous system would develop structures to be employed for their representational properties just in case (or as a consequence) of amputation. The issue here is that amputation, as an evidentiary basis, fails to generalise.

Motor control, however, provides a more plausible basis on which to generalise. A key physiological constraint on motor control is that sensory transmission in the nervous system takes time. This holds especially for the large myelinated axons carrying signals specifying the dynamics of bodily movement. As their conduction velocities are relatively slow—and the distances they must travel within the body are often relatively large—these signals cannot in general travel fast enough to provide a timely influence on central motor processes (Latash 2008b, pp. 70–72). This makes it something of a puzzle how smooth sensorimotor control is achieved, especially where that control involves corrective movements generated before the relevant peripheral feedback could have arrived (Grush 1997, pp. 14–15, 21 n13).

This puzzle is dissolved by positing neurally encoded models of body-parts (Kawato et al. 1987; Wolpert and Ghahramani 2000).[12] These models function

[12] For an overview of these approaches, see Desmurget and Grafton (2000).

as structural representations of the dynamics of parts the musculoskeletal system (Grush 1997, pp. 16–17). The relations between elements of the model are subject to change, in a usefully similar manner to how the elements of parts of the musculoskeletal system are subject to change. Given this resemblance, such a model can then generate predictions about how the dynamics of bodily movement would be affected by an outflowing motor signal. Moreover, as the model is situated within the brain, the outputs of the modelling process are generated before peripheral signals specifying those effects can arrive. Thus, in standing-in for body-parts during inevitable temporal delays in the control process, models of body-parts can facilitate smooth sensorimotor control.

Motor control is one of the earliest and most frequent activities undertaken by the nervous system. Accordingly, it provides a plausible basis on which to generalise to other cases in which body-part representations might serve as stand-ins. There is no architectural restriction on these models such that they could only be used in motor control. Indeed, once trained, models of body-parts could plausibly be employed for generating sensory content, as well as being run ‘offline’, for the purposes of motor planning and imagery.[13]

Moreover, positing models of the body also provides a compelling explanation of the patterning of bodily experiences in the more complete absence of sensory contact characteristic of phantom limbs. Melzack and Bromage (1973) induced phantom limb sensations in healthy subjects by anaesthetising the afferent and efferent nerves of their arms. Whilst subjects remained passive, they reported spontaneous changes in the position of the phantom; when subjects were instructed to try to move their arms during gradual onset of anesthesia, changes in the phantom’s position correlated with retained muscle activity. In a later study, Gandevia et al. (2006) found that movements of the subject’s phantom hand were in the direction of the attempted movement, with variation consonant with the degree of force applied. These phenomena are precisely what would be expected if the representation underlying the experience of the phantom were a dynamical model of the limb.

4.2.2 Body-part models structure information concerning body-parts

Representations fulfil a structuring role where they can enable a cognitive system to settle ambiguities in sensory input, to ensure accurate perception and appropriate action. Such ambiguity is the grounds for a common inference to the existence of models of the body. For instance, Longo and Haggard (2010) claim that a stored body model is required for tasks which concern metric properties, such as size and shape. They infer this from the fact there is no sensory signal that “directly informs the brain about the metric properties of body parts” (Longo and Haggard

[13] In recent years, a significant split has emerged between approaches which posit models that implement a mapping from sensory to motor signals (so called inverse models, see, e.g., Wolpert and Kawato (1998)) and those that do not, in more strict accordance with a general ‘predictive coding’ account of neural architecture (see, e.g., Shipp et al. (2013)). This difference is immaterial for the present purposes, but see Pickering and Clark (2014) for discussion.

2010, p. 11727). This is not (or at least, it need not be) to deny that there are sensory signals which carry information about metric properties, such as the size and shape of a hand. Rather what is being stated here is that no signals do so unambiguously, such that one could map, e.g. hand-shape from these signals directly; it is this that implicates the presence of a model of the hand. In this vein, this subsection will review some of the ways in which the many and various sources of bodily information are crucially ambiguous.

We can get some idea of the quantity of information concerning the body by considering the number sensory channels carrying information about the body. There are sensors within the body dedicated to conveying the state of its parts (through several proprioceptive and interoceptive channels) and its orientation relative to the gravitational field (through vestibular and somatic graviceptive channels). Moreover, visual, auditory, tactual and olfactory sensing typically involves movement of the body-parts in which these sensors are embedded, which in turn will result in changes in proprioceptive input. Consequently, when sensing the environment, the brain will receive input from the extra-neural body that is quantitatively superior to that received from any environmental object (Azañón et al. 2016).

But this sheer quantity of information is perhaps equal in degree to its potential for ambiguity. It is well established that sensory processes are deeply integrated (Stein and Meredith 1993). Yet is also clear that sensory modalities integrate information at different time scales, and even in cases where there are properties to which multiple modalities are sensitive—such as spatial properties—they are differentially sensitive to these (Welch and Warren 1980). Sensory processing of bodily information is no exception in this regard. Indeed, the integration between modalities in determining the size and shape of body-parts is extensive enough that non-informative sight and sounds can result in distorted perception (Longo 2014; Tajadura-Jiménez et al. 2017). Yet, when individuals are required to perform tasks which restrict sources of sensory information, their performance also exhibits distortions reflecting the sensory modality on which they must rely (Longo and Haggard 2010). For instance, Stone et al. (2018) found that participants misjudged the length of their legs when only a tactile measure was used, they misjudged the width of their legs when only a visual measure was used, and they misjudged both when only a proprioceptive measure was used.

The problem of ambiguous signalling is not merely a problem of multisensory processing, nor is it a problem confined to metric properties of the body. To see this, consider the signals conveyed by muscle spindles. These are the largest, fastest and easily the most complex of the class of receptors Sherrington (1906) dubbed as proprioceptors. Each muscle spindle is a complex of nerve endings integrated with central (intrafusal) fibres of skeletal muscle, which are themselves integrated into the greater (extrafusal) bulk of the surrounding muscle. These nerve endings fire when stretched—typically as a consequence of a muscle stretch—and a subset of them are also sensitive to velocity (Widmaier et al. 2019, pp. 305–307). They are generally considered to convey information about limb position—an idea bolstered by illusions of limb-position created through muscle spindle stimulation (Matthews 1988). If a muscle's tendon is vibrated at 100 Hz, low amplitude changes in muscle-length drive the velocity-sensitive receptors within. A train of nerve impulses relayed through the spinal cord drives a sympathetic response in the muscle's antagonist, resulting in an involuntary movement, akin to a stretch-reflex. If this movement is gently checked, the artificially stimulated spindles will continue to fire in a manner consonant with lengthening of the muscle, despite the fact that the muscle is not getting any longer. A subject in this condition, required to track the angle of the stimulated arm by matching it with the non-stimulated arm, would typically continue to extend the latter well after the former's movement has been checked—indicating that the artificial stimulation had generated an illusory experience of arm position (Goodwin et al. 1972a, b).

However, as Mark Latash argues, even if the nervous system evidently deploys muscle spindle stimulation as a source of information about limb position, the signals that they can provide are inherently ambiguous in this regard (2008a, pp. 258–259). As noted above, the nerve endings in muscle spindles are stretch-sensitive. But activation of a muscle produces contraction. So, if spindles only fired when the muscle was extended (relaxed), signalling would drop off entirely when a muscle was fully activated. This does not occur, because the motoneurons activating the bulk of the muscle are paired by reflex with motoneurons contracting the central muscle fibres in the opposite direction, thus preserving the muscle spindle signal. But what this means that very similar muscle spindle activity can occur when (1) a muscle is activated and its attached limb *is moved*, and when (2) a muscle is activated and its attached limb *does not move* due to external forces (Burke et al. 1978). Yet these two situations are precisely what a system for determining limb position should differentiate. Reviewing similar issues with other proprioceptive channels (from receptors in the tendons, joints and skin) Latash observes that overall the proprioceptors produce a rather "messy stream of sensory signals" (2008b, p. 76).

Despite the wide-ranging imperfections of our senses, it is nevertheless striking that we are able to accurately experience and appropriately act with our bodies. This clearly suggests a structuring role for body-part models, filtering the messy stream of (multi-)sensory input to make manifest properties such as the size, shape and position of body-parts. This panoply of cases makes vivid the fact that models of body-parts need not only serve as stand-ins.

Indeed, the models structuring information concerning body-parts might be the very same dynamical models which serve as stand-ins. For instance, Rabin and Gordon (2006) found that vibration-induced illusions were attenuated in tasks where subjects were required to stabilise the limb during stimulation. And Naito et al. (2002) found that imagined movements systematically modulate proprioceptive illusions induced by tendon vibration. Again, these are just the kind of phenomena that would be expected on the assumption that the form of the relevant representation is a dynamical model (Sadato and Naito 2004).

I should note two kinds of challenge to the line of argument taken in this section. The first is that there may be wholly non-representational solutions to the kinds of problems raised here (see, e.g. Di Paolo et al. 2017, pp. 223–226). Although I do believe that a comparison of the relative merits of such accounts is a natural extension of the present work, it is beyond my aims here. The second kind of challenge is one that might be raised by a proponent of the standard view—namely, that despite the fact that all the tasks and phenomena discussed concern individual body-parts, our explanation might nevertheless require appeal to a model of the body as an integrated whole. The rest of this paper is dedicated to developing and disputing such an account.

5 The standard view and the minimal view

5.1 Making the case for the standard view

Some proponents of the standard view have, on occasion, made passing remarks to suggest that a model of the body as an integrated whole stands-in for the body itself. For instance, when introducing his central notion of a *phenomenal self-model*, Thomas Metzinger writes:

> You are never in contact with your own body—as an embodied, conscious entity you are the contents of an image, a dynamical image that constantly changes in a very high number of different dimensions. (2003, p. 301)

From the context of remarks like these, it is clear that they are not supposed to form an argument in favour of positing such a model. And I think it would be unfair to treat them as such. Indeed, Brian O'Shaughnessy, an influential proponent of the standard view, is at great pains to reject a similar idea he evocatively dubs as "the myth of Hypostatised Interiority" (1980/2008, p. 247).

Still, it is worth clarifying why a case like this would be hard to make. The first difficulty is in establishing the coherence of the basic premise for positing a stand-in for the body as an integrated whole. For it is not clear how one should appropriately develop the idea that the body is absent. This is no issue in the case of body parts. In the most extreme cases of amputation or sensory loss, a sensory signal that was once present, connecting the representation and its target, is now absent. But in the case of the body as an integrated whole, this contrast between presence and absence does not get a grip. It might be suggested that we need a more inclusive notion. But the body as an integrated whole is never 'absent' nor is it ever 'present', on reasonable extensions of the terms. It is never absent, in that sensory input is only ever completely lost for individual parts of the body—and never all parts of the body at once. But, then again, it is never present, in that there is no sensory channel dedicated to the body as an integrated whole.

Assume, though, for the sake of argument, that there is some way of ironing all this out. That is to say, let us assume that there is some clear sense in which the brain must deal with the absence of the body as an integrated whole. Even if this were right, one would still need to make the further case that *this role*—the role of being a stand-in—is not a role that could be collectively fulfilled by models standing-in for all the body's represented parts.

At this point, it is worth recalling that the standard view's aim is to provide an account of the structure of bodily experience and action (see Sect. 2):

> **The standard view**: An explanation of the structure of bodily experience and/or bodily action, must posit a representation of the body as an integrated whole.

With that in mind, one might deploy a looser notion of presence to say that an account of how the integrated structure of the body can be 'present' within the cognitive system requires a model of the body as an integrated whole. That is to say, an explanation of the structure of bodily experience and bodily action must involve positing an internal entity with the very same structure.

But it is not clear this requirement ought to be accepted. Nor is it clear why, if it were accepted, it would yield anything more than a superficial account of the relevant phenomena. In this, I join Ruth Millikan in her suspicion that this kind of move involves a form of the vehicle-content conflation error:

> The error is that of projecting, without argument, chosen properties of what is [represented] onto [representations], and vice versa. The error is equally that of taking this sharing of properties to constitute an explanation of mental representing.[14] (Millikan 1993, p. 258)

On proper consideration, proponents of the standard view hold a more refined position. The key claim is that a model of the body as an integrated whole is a higher-order structure which determines the coordination of parts of the body (de Vignemont 2018, pp. 160–161; de Vignemont et al. 2006, p. 148; Metzinger 2015, pp. 273–274; O'Shaughnessy 1980/2008, pp. 276–280). Thus, the rationale for positing a representation that encodes the body's structure is not simply that the body has that structure, for this would indeed risk vehicle-content conflation. Rather the rationale stems from the mutual dependence between parts constituting that structure.

This mutual dependence can be appreciated by contrasting two ways in which parts of the body might be represented in a model of the body as an integrated whole. One way of representing body-parts in such a model might be as what Casati and Varzi usefully refer to as 'components', where "a component of *x* is a distinguished part of *x*, a part that is available as an individual unit regardless of its combining with other parts" (1999, p. 32). Components are independent of one another. Representing body parts as components would only be adequate for tasks in which parts of the body can be treated as independent from one another.

If parts of the body were claimed to be represented in the manner of components, this would clearly fail as an explanation of the structure of bodily experience and bodily action. For that structure is that of a whole composed of interlocked parts. In bodily experience, parts of the body are experienced as parts of a greater whole; in bodily action, parts of the body mutually constrain bodily movement due to the nature of their connection. To adequately represent each part in a manner that might manifest this structure, the system must coordinate individual body-part representations in a manner that is sensitive to each body-part's interlocking.

[14] See also the methodological variant of what Cantwell Smith (1996, pp. 50–54) refers to as an 'inscription error' and McDermott (1976) on 'wishful mnemonics'.

The standard view presents an obvious way of achieving this: integration of structural information about all parts of the body in a model of the body as an integrated whole. This model would then serve as a constraint for models of individual body-parts. By computing over a model of the body as an integrated whole, a system can employ structural information to modify individual models of body-parts in a manner that is sensitive to the properties of other body-parts.

5.2 Parsimony and exploitative body representation

We are now able to adjudicate whether positing a model of the body as an integrated whole is indeed required to explain the structure of bodily experience and action. The minimal view denies this.

> **The minimal view**: Given the nature of the body itself and representation of its parts, an explanation of the structure of bodily experience and/or action need not appeal to a representation of the body as an integrated whole.

Note that the minimal view does not deny the existence of body representations—central to the view is an appeal to representations (viz. models) of body-parts. However, it also gives an explanatory role to the body itself. That role is to explain how models of body-parts are coordinated: the minimal view claims that the body itself can serve to coordinate body-part models, as the parts of the body itself are structurally interlocked. Thus, the body itself, on such a view, would serve the very same explanatory role proposed for a model of the body as an integrated whole, in so far as it would explain how representations of parts are coordinated.

It ought to be clear that both views we are considering posit the same entities but one. For both agree to the existence of models of parts of the body. And both agree to the existence of the body itself, the existence of its parts, and their relations as an integrated whole. On the minimal view, this is all that is required; on the standard view, what is further required is a model of the body as an integrated whole. Thus, the basic argument for the minimal view is an application of the modesty constraint. The minimal view is more parsimonious than the standard view; if it is equally plausible, it ought to be favoured. The aim of the remainder of the discussion is to show that it is equally plausible.

Recall that the standard view explains the coordination of models of parts of the body by appeal to a model of the body as an integrated whole. This model encodes structural information about the relations between parts of the body, which can then serve to constrain models of body-parts. On the minimal view, the body itself—an integrated whole, consisting of inter-related parts—serves this explanatory role. There is no need for a model of the body as an integrated whole. Rather than being constrained by an overarching model encoding relations between body-parts, models of body-parts are constrained by the relations between body-parts themselves. Rather than these relations being treated as relations that need representing in an overarching model, the minimal view takes them to be relations that can be ‘exploited’, in the sense of ‘exploitative representation’ described by Robert A. Wilson. To convey the notion, consider his example, in which he compares two ways of building a device for keeping a tally of how far a car has travelled:

> One way it could do this would be for the assumption that 1 rotation = x meters to be part of its calculational machinery [...] Another way of achieving this end would be to be built simply to record x meters for every rotation, thus exploiting the fact that 1 rotation = x meters. In the first case it encodes a representational assumption, and uses this to compute its output. In the second, it contains no such encoding but instead uses an existing relationship between its structure and the structure of the world. (Wilson 2004, p. 163)[15]

On the minimal view, a non-representational strategy along the lines of the second device Wilson describes can be used to exploit 'an existing relationship' within the structure of the body. The structure of the body—at least, the relevant structure—consists of various kinds of causal connection. Causal connections between parts include hinged limb-segments with overlapping musculature, often arranged in antagonistic pairs, and connective tissue structures running the length of the body (see, e.g. Turvey and Fonseca 2014). Parts of the body mutually affect one another by these means, collectively constraining movement possibilities. Certain causal properties are only attributable to the body in its entirety, such as its total mass, the velocity of its rotation, elevation and translation, its centre of gravity etc. Thus, the causal structure of the body involves causal interactions between parts and the entire body, in virtue of the distinctive properties of each.

The ways in which the two views treat these causal relations and the elements that they govern is important in understanding their difference. So, it will be useful to have a way of referring to all these with some brevity. Employing some simple notation from Alsmith (2017), we can label body-parts $\pi_1 - \pi_n$ and the integrated whole that they comprise as ω. We can also call Π the relation of part-part causal interaction and Ω the relation of part-whole causal interaction; together, these govern $\pi_1 - \pi_n$ such that they form the structure ω.

The contrast between the two views is then as follows. The standard view claims we need to posit a model of ω to ensure that models of $\pi_1 - \pi_n$ are coordinated according to Π and Ω and thus reflect ω. By contrast, the minimal view claims that relations Π and Ω can be exploited, such that models of $\pi_1 - \pi_n$ can be coordinated without the system modelling ω.

The next sub-section will give a sketch of the mechanism by which coordination of models of $\pi_1 - \pi_n$ (without modelling ω) would be achieved.

5.3 Adapting to bodily structure

On the standard view, the question of why models of $\pi_1 - \pi_n$ are coordinated according to one set of relations rather than another is best answered by recourse to a model of ω. The task of modelling ω is complicated by the fact that ω itself can

[15] *Cf.* also the discussion of 'minimal memory strategies' in Ballard et al. (1997, p. 732).

change over time. Changes can occur in the size, shape, weight and rigidity of body-parts. Such changes are part of the natural course of development, but they can also occur in maturity, through amputation, prosthesis and tool-use. These changes are significant in so far as they result in differences in causal interaction: a model might misrepresent ω because it encodes *Π* and *Ω*, whereas ω is now governed by different causal relations *Π'* and *Ω'*.

A proponent of the standard view might respond that these changes can be accommodated by feedback from the body serving as a means of gradually changing the model according to its new structure. But this is only plausible on the assumption that this occurs through changes in body-part models, and for two reasons.

First, as noted earlier, there is no sensory signal dedicated to the body as an integrated whole, whereas sensory feedback concerning body-parts is readily available on an ongoing basis. Second, it has long been established that models of body-parts are *adaptive*, in the sense that their content can be updated through feedback from that which they represent (Bhushan and Shadmehr 1999; Shadmehr and Mussa-Ivaldi 1994). What the standard view must claim is that a model of the body as an integrated whole is adaptive in an analogous respect. Changes in a model of the body as an integrated whole occur in response to changes in individual body-part models, which are themselves responses to changes in the body-parts they represent.

This reveals the redundancy of appealing to a model of the body as an integrated whole in an account of how models of $\pi_1 - \pi_n$ are coordinated. On the standard view, the question of why models of $\pi_1 - \pi_n$ are coordinated according to *Π'* and *Ω'* rather than *Π* and *Ω* is supposed to be answered by recourse to a model of ω encoding the former rather than the latter. But the question of why the model of ω encodes one set of relations rather than the other is answered by recourse to models of $\pi_1 - \pi_n$ imparting the structure of ω on the model of ω. It is not clear, then, why we should appeal to a model of ω to explain the coordination of models of $\pi_1 - \pi_n$. For any structure in the model of ω that would enable such coordination must be due to structure transferred through models of $\pi_1 - \pi_n$.

On the minimal view, models of $\pi_1 - \pi_n$ are coordinated by the structure of ω itself. Each body-part model represents an individual body-part, which is itself structurally interlocked with other parts of the whole. As each body-part model is adaptive, each represents its target in a manner that fits its (new) place in the structure of the whole. For each model adapts in a manner that is due to the (new) causal interactions between individual parts and the whole. In other words, changes in models of $\pi_1 - \pi_n$ are due to ω being governed by *Π'* and *Ω'* rather than *Π* and *Ω*. Consequently, models of $\pi_1 - \pi_n$ will be coordinated according to the contemporary structure of ω. However, the coordination here is due to individual models adapting to feedback from individual body-parts which themselves form an integrated whole. It is not due to individual models being coordinated by a model of the body as an integrated whole.

Before moving on, let me put aside the contrast with the standard view, to state the minimal view and its consequences a little more plainly. On the minimal view, body-part representations are models of their targets. The structure of bodily experience and bodily action requires coordination of body-part representations. On the minimal view, this coordination is achieved by models adapting—through sensory feedback from the body-parts they represent—resulting in their coordination according to the actual interlocked structure of the body. If a model of a body-part is maladaptive, it will not reflect the properties of that body-part which are causally affected by structural connection to the rest of the body. Consequently, the coordination of body-part representations will be dysfunctional, and this will affect the subject's experience of her body and her ability to act with her body. Moreover, it will have various manifestations that might be revelatory of the cause of the maladaptive process, such as reports of unusual bodily experiences, motor deficits, and correlated physiological abnormalities in sensory or motor processing.

6 Other arguments in favour of the standard view

Whilst I think that the most robust case for the standard view is the one presented in Sect. 5.1, it is not the only case found in the literature. It would be remiss not to mention three other kinds of considerations that are occasionally mentioned—illusions and hallucinations involving the whole body, innate representation of the body, and the desire for body-part amputation—if only to indicate how I think they fall short of supporting the standard view.

6.1 Full-body illusions

One way of independently motivating the standard view would be to claim that positing a model of the body as an integrated whole is required to explain illusions and hallucinations that seem to involve the whole body (Metzinger 2005, 2007, 2009; Metzinger and Blanke 2009). For instance, in the *full-body illusion* subjects observe a virtual body being stroked on its back, whilst being stroked on their own back in a synchronous fashion (Ionta et al. 2011; Lenggenhager et al. 2007, 2009).[16] In many subjects, this yields reports of identifying with the observed body and self-location judgements that are biased towards the projected position of the avatar. Illusions of this kind are often compared to heautoscopic experiences and out-of-body experiences. In a heautoscopic experience, a subject may hallucinate seeing a body that seems like their own body. In an out-of-body experience, a subject may hallucinate leaving their actual body and seeing it from a distance.

These cases seem to involve misrepresentation of properties that can be attributed to the whole of a subject's body, such as its location or translation, or even the property of being the subject's body itself. The difficulty with these cases as motivation for positing a model of the body as an *integrated* whole is that to the extent that

[16] Henrik Ehrsson's lab uses a similar multisensory stimulation protocol to generate a *body swap illusion*, see Ehrsson (2007), Petkova and Ehrsson (2008). See Blanke (2012); Serino et al. (2013) for reviews. In recent work, Andrea Serino and colleagues have pursued the hypothesis that there is a "general representation of the space around the body [to] which other smaller body-part centered representations are referenced" (Serino et al. 2015, p. 11). Though this might not be, strictly speaking, a version of the standard view, there are similar issues to be worked out here, for which see (Alsmith forthcoming).

they involve misrepresentation of these properties, they involve representation of the body as a single thing. In general, representation of something as a single thing need not involve encoding any information about its parts. Accordingly, even if, as is likely the case, the body is represented as a single thing for various purposes (such as judging one's location, thinking of one's body as own), this need not involve any information about its parts, or indeed, more crucially, their structural relations. By contrast, to model the body as an integrated whole, in the sense required at least, is to encode precisely this kind of information. For it is only in virtue of this that a model of the body as an integrated whole can serve the explanatory role of coordinating representations of parts of the body.

6.2 Innate body representation

Moving now to innate representation: expressing his famous concept of the 'neuromatrix', Ronald Melzack writes that it is "likely that a genetically built-in matrix of neurons for the whole body produces characteristic nerve-impulse patterns for the body and the myriad somatosensory qualities we feel" (Melzack 1990, p. 91). If we read the expression "matrix of neurons for the whole body" here as "representation of the body as an integrated whole" (rather than merely as a single thing), then any argument in favour of such an innate representation of the body ought to be an argument in favour of the standard view.

Where support is provided for innate representation of the body, typically it is provided by appeal to either phantom limb experience or neonate imitation (Gallagher and Meltzoff 1996; Meltzoff and Moore 1983, 1997; Melzack 1990; Rochat 2010). The most compelling case from phantom limb experience draws upon reports of sensations in limbs that have been congenitally absent (Brugger et al. 2000; Melzack et al. 1997). However, such cases are just as well explained by a developmental account, according to which morphological similarities between an aplasic individual and their conspecifics affect the individual's body representation (Bremner 2017; Price 2006).[17] And the case from neonate imitation is based upon controversial empirical grounds, with a recent longitudinal study only finding imitation from 6 months of age (Oostenbroek et al. 2016).

Besides these issues is a greater problem. For even if a strong nativistic case could be made for either aplasic phantoms or neonate imitation, it is not clear that such a case would require innate representation of the body as an integrated whole, as opposed to merely innate representation of limbs or faces. The tendency to move so smoothly from potential evidence for innate representation of individual body parts to a representation "for the whole body" shows, I think, that the standard view has been considered the only plausible view in the vicinity.

[17] See also Longo's (2017, p. 86 ff.) discussion of body representations being biased towards prototypical representations of the body.

6.3 Body identity integrity disorder

Another case for the standard view might be made by appeal to *body identity integrity disorder* (BIID). This condition (sometimes known as *xenomelia*) is characterised by a long-term desire to be disabled, either through amputation or loss of the use of a limb (First 2005; First and Fisher 2012). The basis and manifestations of this desire are so varied that some have proposed that the condition is best characterised as a spectrum (Brugger et al. 2013). However, it is often manifest through attempted self-amputation and expressions of a feeling that the body parts in question are not parts of themselves. As one individual with the desire to amputate his leg puts it: "I feel myself complete without my left leg … I'm over-complete with it" (First 2005, p. 922).

A proponent of the standard view might well see such reports as supportive evidence. As Carruthers writes "it seems that the existence of body integrity identity disorder does provide grounds for supposing that there exists an integrated offline representation of the body" (2008, p. 1311). Carruthers' notion of an *offline body representation* is similar to O'Shaughnessy's *long-term body image* and de Vignemont's *body map* in the sense that it "represents what the body is usually like. It represents that one has two arms [and] not, for example, exactly where one's limbs are currently" (Carruthers 2008, p. 1314). Carruthers (2008, p. 1311) suggests that the main competing hypothesis is that BIID reports are solely due to some more general abnormality in belief and desire formation. This need not involve misrepresentation of the body as such, but rather, for example, a frustrated social or sexual identity (see, e.g. Lawrence 2006). Carruthers then infers that if BIID reports reflect not only the beliefs and desires of those who suffer with syndrome, but also their bodily experience of their undesired parts, then this serves as "grounds for supposing that there exists an integrated offline [mis]representation of the body" (*op cit.*).

The existence of the minimal view as alternative undermines that inference. And it is certainly not exclusively supported by the available data. Several imaging studies have demonstrated that BIID sufferers exhibit unusual activity in areas the brain involved in somatosensory processing, such as the premotor cortex (Giummarra et al. 2011; van Dijk et al. 2013). But to see this as solely supporting the standard view would be to, once again, fail to note the availability of the minimal view as an alternative. Indeed, there is no clear consensus in the literature on whether the neural bases of BIID ought to be construed as a failure of representation of the affected body part alone or a representation of the body as an integrated whole (cf. Blanke et al. 2009; Hilti et al. 2013). This is hardly surprising, as both the minimal view and the standard view would likely appeal to the very same disruptions in sensory processing of the rejected body-part in accounting for the phenomenon.

7 Conclusion: does the argument prove too much?

A final objection might emerge in the reader's mind that, whilst I have attempted to retain a moderate representationalist stance, my arguments in Sect. 5 prove more than I have observed. For surely, a similar form of the arguments I have run against positing a model of the body as an integrated whole can also be run against positing models of body-parts.

What is useful about this objection is not so much its content, as its form. Depending on the views of the objector, such an objection can lead to very different conclusions. It can either seem that my arguments carry (rightly!) through to the claim that there is no need to posit representations of the body *tout court*; or it can seem that there must be some flaw in my arguments because they (absurdly!) lead to such a conclusion. But the very purpose of following the framework of seeking explanatory roles for representations is to get away from the dogmatism that might move one to such conclusions without proper warrant.

Indeed, few contemporary theorists commit to a thoroughgoing anti-representationalism across the board.[18] Many theorists sceptical of representational explanation opt for a hybrid or 'duplex' view in which one attempts to, as far as possible, explain phenomena without appeal to representation, admitting to representational posits only where they are explanatorily potent.[19] One might thus call the minimal view 'narrowly' duplex: narrow in so far as it concerns only representations of the body; duplex in so far as it accepts that representations of body-parts are well-suited to serve key explanatory roles, namely as models that stand-in for their (intermittently) absent targets and structure information concerning their targets.

Still, to accept that body-part representations are well-suited to serve such a role is not to fully demonstrate that they do so. For that would require fully engaging with a non-representational alternative. *That* challenge remains, to be taken up elsewhere. Until it is met, it cannot be said that we have achieved anything like establishing the truth of the minimal view, only that it should be favoured over the standard view, and for roughly these reasons: There cannot be any deadwood representations; in each case, the rationale for positing a representation must be clear and almost irresistible. Given the nature of the body, the rationale for positing a representation of the body as an integrated whole is not at all clear and certainly resistible. This is so, specifically in those cases in which positing a representation of the body as an integrated whole seems *prima facie* most compelling, namely cases in which we experience or act with our bodies as an integrated whole.

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[18] See Chemero (2009) for a notable exception.

[19] Though, there is some variance amongst duplex theorists as to when representational explanations are explanatorily potent: cf. Hutto and Myin (2012, 2017) and Clark (1997).

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