Acting on (Bodily) Experience*

Abstract

The complexities of bodily experience are outlined; its spatial phenomenology is specified as the explanatory target. The mereological structure of body representation is discussed; it is claimed that global spatial representations of the body are not necessary, as structural features of the actual body can be exploited in partial internal representation. The spatial structure of bodily experience is discussed; a *structural affordance theory* is introduced; it is claimed that bodily experience and subpersonal representation have action-oriented content; and that egocentric terms continue to make sense in application to bodily experience.

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If we assume that bodily experience has spatial content, we find ourselves in a mire of rather complicated issues. I want to discuss two that seem interrelated, devoting a section to each. The first issue (discussed in the second section) concerns the mereological structure of body representation. *Body mereology* is the study of body-part-to-part and body-part-to-whole relations.[1] Recent discussions in this area (e.g. de Vignemont et al., 2006), though illuminating, have tended to focus upon part-to-part relations. I intend to make progress upon the relationship between parts and the whole. I suggest that the body itself provides a systematic unity that is lacking in partial neural representation. The second issue (discussed in the third section) concerns the spatial structure of bodily experience. I address a recent claim that bodily experience is not egocentrically structured. In doing so, I combine insights from earlier discussions to introduce the novel theoretical notion of a *structural affordance* and apply a well known account of egocentric spatial representation to bodily experience, whilst noting (and bracketing) the complications introduced by intermodal influences. However, before we get into all that, it would be nice to say a few general things about our target phenomena: bodily experiences. This will be our topic for the first section.

1. The Complex Phenomenology of Bodily Experience

The term ‘bodily experience’ (or its cognate ‘bodily awareness’) admits of various different modes. Of these one might discern three super-ordinate modes – *visceroception*, *somatic proprioception* and *somatosensation* – with respective sub-dimensions. I take each of these in turn, providing in each case a number of phenomenological or functional features, in the following (painfully short and certainly not exhaustive) commentary.

Take, as a start, *visceroceptive experience*. Characterized by a driving emotional tone, the set of visceral experiences includes the occasionally visceral feelings of emotions, as well as hunger, thirst, feelings of satisfaction or bloatedness, indistinct feelings of physical effort, pleasurable experiences such as orgasm, and the voluptuous feeling arising from muscle after exercise.

This is at least conceptually distinct from *somatic proprioceptive experience*: experience of the dynamic or static comportment of one’s limbs and/or one’s body as a whole. In the latter case, Gibson (1979) noted that any sensory flow field could provide such information – but the qualifier “somatic” here is meant to exclude proprioceptive features of visual, or auditory flow fields. Rather what I wish to denote here are such phenomena as the kinesthetic sense of bodily movement, the postural/vestibular sense of personal comportment (in the relation of one’s torso to the gravitational field), and the joint positional sense of respective limb location and recursive angular relation to the torso.

For some, all of these come under the general heading of *somatosensory experience*. But it would be more precise to preserve this term to pick out the range of experiential phenomena that arise from bodily contact. These are often characterized in terms of their dual exteroceptive and interoceptive capacity, due to the potential for attentional oscillation between contacted and contacting surfaces (Gallagher, 2003; Bermudez, 1998). Functionally,

[1] This term was first introduced by de Vignemont et al. (2006).

experiences under this general heading are subserved by both cutaneous and sub-cutaneous receptors. For instance, cutaneous receptors enable what is often called "basic touch": any static tactile sensation in bodily/non-bodily contact, including tickles and flutters. They also enable, though do not fully determine, "haptic touch": the exploratory, discriminative tactual perception of bodily/non-bodily objects. As well as itches and surface nociception (painfully experienced damage to surface bodily tissue). This is in contrast to various *sub*-cutaneous sensory phenomena, such as pressure, vibration, and deep nociception (painfully experienced damage to deep bodily tissue).

Despite this complex range, what I am really interested in is the assumed *spatial content* of bodily experience, thus bodily experiences will be relevant to this discussion *only* in virtue of their (albeit sometimes rather vague) spatial phenomenology, rather than any other intermingling aspects of their phenomenology.

I certainly agree that, even with this more narrow focus, differentiating various aspects is still problematic. In the first place, it would be foolish not to note the considerable cross-talk and interdependencies in and between the various bio-mechanisms that enable bodily experience on the one hand, and the modular organization of some of these mechanisms on the other. This invites careful proceeding. One must be sure to note that the flow of information at the sub-personal level admits of various degrees of integration and dissociation that may not show up as such in the phenomenology (Eilan et al., 1995, pp. 12 – 14). In addition, any particular bodily experience might involve a concomitant blend of visceral, somatosensory, and/or proprioceptive elements, and even top-down or intermodal contributions from distal sensory modes such as vision.[2]

As I said, I am strictly confining my discussion to the spatial phenomenology of bodily experience. But, whilst the explanatory target is well specified, the target phenomena are themselves *imprecise* and *ambiguous* in ways that crucially complicate explanation. *Imprecision* is inherent in the possibility of vague spatial phenomenology, or indeed grades of spatial determinacy. Many aches for instance, or feelings of muscular fatigue, are experienced at spatial locations (or regions perhaps) that are notably indeterminate. The imprecise nature of such spatial phenomenology makes it rather difficult to provide anything like a *framework* that captures it. *Ambiguity* is inherent in the existence of a criterial choice in discerning sameness of bodily location, for it is possible to specify bodily locations in ways that are independent of movement *and* ways that are dependent upon movement.[3] An account

[2] Many have noted this point, but in different ways, see for instance: Craig (2002, 2003); Eilan et al.(1995, pp. 13-14); Kinsbourne (1995, p. 213); Gallagher (2001, footnote 3); Haggard et al. (2003, p. 170). Also see footnotes 5, 6, & 7, as well as subsection 2.1 and section 3 on crucial intermodal relationships.

[3] Bermudez (2005, pp. 310 – 311) notes the problem with characteristic insight, suggesting that we distinguish A-locations (independent of movement) from B-locations (dependent upon movement), while nevertheless maintaining that all bodily locations have frames of reference anchored to nearby joints. The crucial difference being whether or not one factors in potentially changing angular relations to the torso as an ultimate anchor point. Thus the A-location of the pain in my left thumb as I strike it with a hammer remains the same despite my waving it around in agony or bringing it closer to my face to inspect the damage. Whereas the B-location of the very same pain is specified recursively back to the immoveable torso as a function of the relative angles of each limb as it rotates about its joint(s). So the B-location changes constantly as I wave my thumb about. Note that the two

of the spatial content of bodily experience ought to provide a frame of reference that can accommodate both static metric relations as well as the dynamic and interlocked structure of mobile bodies.

The task of providing an account that deals with both imprecision and ambiguity is part of the more general challenge of ensuring that the spatial content specified is experiential content. One needs more than a corporeal frame of reference – a frame of reference conceptually bound to the spatial aspects of animal bodies. What one needs is a frame of reference conceptually bound to *experiencing* the spatial aspects of animal bodies: an *intra-*corporeal frame of reference.[4] In what follows I take on this task, in an effort to lay down a path to its future completion. For now though, a few words on the next section.

As already stated, at the very least any intra-corporeal frame of reference must be conceptually bound to an animal body, presenting locations within the dynamic and interlocked structure of that body as potentially mobile. This structure can be analyzed along two dimensions, in terms of body-part-to-part relations, and in terms of body-part-to-whole relations. Few distinguish these dimensions (see de Vignemont et al., 2006 for an excellent exception), and those that do, tend to focus upon part-to-part relations (perhaps for good reason). Intuitively body-part-whole relations are crucial, both in representation of the spatial orientation of parts and experience of the body in its spatial aspects. In the next section, I examine the issue of whether there are in fact such part-whole relations internally represented, firstly in sub-personal representation of bodily space, and secondly in personal level experience of attending to the body.

2. Part of the Whole

A general issue for biological systems realizing conscious experience is the dual-achievement of maximal integration and differentiation (Tononi & Edelman, 1998). Here is the problem in application to body representation: At the sub-personal level, there seems to be a tension between the piecemeal spatial representation of body parts, and the clearly necessary task of co-coordinating these parts as a synergetic whole. At the personal level, there seems to be a tension between fleeting moments of focally attending to parts of the body, and a background sense of the body as a whole. In fact, I think that these tensions are a natural corollary of the claim that the brain needs to encode an articulate, globally integrated

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are compatible in certain cases: their difference makes no difference if the location in question is in (or on) an immovable body-part (Bermudez, 2005).

[4] Arguably Bermudez's (2005, p. 311) A/B-locations analysis fails to meet this challenge, despite his stated aim of capturing certain phenomenological facts. On his account spatial content can be specified either in terms that account for changes in joint-angular relations stabilized relative to the torso, or not. This provides the possibility of a distinct dynamic analysis that is compatible with a static analysis of mere metric relations, where distance and direction from the nearest anchoring joint (including respective joint angles accordingly), may thus be discerned with both metrical *and* geometrical precision. But, as noted earlier, unqualified precision does not allow for the possibility of vague spatial phenomenology, or indeed grades of spatial determinacy. A second, trickier point is that the analysans are neither necessary nor sufficient for the instantiation of the analysandum: joint angles (etc.) are no part of immediate spatial phenomenology as such (not necessary); and A/B-locations are thoroughly 3rd personal, and thus readily discernable upon a lifeless corpse (not sufficient).

model of the body in both cases. This is, at least, a logically possible option. I suggest, however, that the problem dissolves somewhat if one considers brain and body as a functional unit. The suggestion being that the unity of the body itself provides requisite synergy in relating represented parts, *without* requiring said unity to be internally represented. The following section is divided into two, unpacking the problem and suggested solution at sub-personal and personal levels respectively.

2.1. The Sub-personal Level

Space 'near' the body is well studied in neuroscience, and is commonly called 'peripersonal' space, as contrasted with 'far' or 'extrapersonal' space. The distinction makes sense only in virtue of distinct functional profiles: Extrapersonal spatial representation is geared towards locomotion and navigation. Peripersonal spatial representation is geared towards reaching and grasping interactions, obstacle avoidance, negotiation and so forth. Despite the functional distinction, there do not seem to be abrupt cut off points: The relationship between the two is currently best understood as a matter of degree, which might vary as a function of limb length and/or height (Longo and Laurenco, 2006, 2007). Furthermore, the relationship between peripersonal space and the body surface should not be rigidly conceived. For it *includes* the body surface, such that visual and tactile spaces are deeply intertwined in spatial representations of the body.[5] To quote one excellent review paper, "It may be very difficult to separate the neural systems involved in representing the body itself from those that represent the space around the body" (Holmes & Spence, 2004, pp. 103 – 104).[6]

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[5] This is illustrated by some excellent neuropsychological studies. Certain patients with right-hemisphere lesions are able to detect individual stimuli (light flashes, touches) on either side of their bodies, on or near their hands for instance. But when presented with *simultaneous* stimuli on symmetrically opposite sides of the body they are only able to detect a stimulus on their *right* (ipsilesional) side, a phenomenon known as 'extinction'. Extinction may occur within a particular modality, such as vision *or* touch – known as unimodal extinction – or it can occur *across* modalities, such as vision *and* touch – known as crossmodal extinction, in this particular case *visuotactile* extinction. Visuotactile extinction has been reported in case studies involving visual stimuli presented in spatial regions proximal to the hands (di Pellegrino et al., 1997), and also in regions surrounding the arms, the face and the head (Mattingley et al., 1997; Làdavas, 2002). All of which suggests that the brain systematically integrates tactile information, concerning the superficial surface and/or orientation of a particular body part, with visual information concerning the space surrounding that part. Generally speaking, bodily proximity is an important variable in these studies (roughly ≤70cm: see Làdavas et al. (2000) for some investigation).

[6] There is a range of psychophysical data that is convergent with the neurophysiological data in this regard. For instance, Spence et al. (2004) asked subjects to hold multisensory stimulus cubes: containing vibrotactile stimulators, placed where they gripped the cube with their forefinger and thumb respectively, and LEDs visible at respective forefinger and thumb locations. There were thus four possible stimulus locations, for two possible stimulus modalities. While holding the cubes participants were required to fixate a central point situated midway between their two hands, held equidistant from the midline. Their task was to determine the location of a single tactile stimulus delivered either to the

Yet this deep integration is both *local* and *plastic*. It is *local* in the sense that it only occurs for particular body parts, or parts embedded in parts: a hand or a whole arm, a face or a whole head.[7] It is *plastic* in the sense that the extent to which visual information is integrated with tactile reliably exhibits sensitivity to the functional range of action effectors located in the relevant regions. This is notably evidenced where that functional range is extended by the active use of a tool such as a rake, or hockey stick.[8]

Now, one might be tempted to posit a singular dynamic process governing the global control and coordination of posture and movement. This might be understood as a neural representation of the spatial properties of the body as a whole – a global representation in which spatial information derived from a variety of sensory modalities (individually coded in body-part centered coordinates) is updated constantly and processed holistically, priming the nervous system to both initiate a complex of appropriate operations and inhibit inappropriate operations. Though tempting, this hypothesis is unsupported, as it has yet to be demonstrated that there exists anything like a fully integrated neural representation of peripersonal space.[9] A more parsimonious explanation of the data posits *only* the existence of multiple body-part centered representations, centered, for example, on the hand, or the arm, or the retina, or the head, or the torso etc (see footnotes 5, 6, & 7).

Now it does seem right that PP spatial representation involves an automatic sensorimotor interface, perhaps crucial in the negotiation and avoidance of objects near to and/or approaching the body. And clearly embodied agents can (and do) negotiate their local

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thumb or the forefinger of either the left or right hand, while ignoring a visual distracter presented simultaneously at one of the four locations. This setup reliably produced a *crossmodal congruency effect*: when visual stimuli appeared at the same location as tactile stimuli, reaction times were drastically faster and fewer tactile discrimination errors occurred (see Spence et al., 2004). Again this suggests, at the very least, a dense integration of visual and tactile information concerning the relevant region.

[7] Single neuron recording studies have repeatedly documented both cortical and subcortical neural populations with multimodal receptor fields centered upon particular body parts. For example, Fogassi et al (1996) report that 56% of the cells in area F4 of the ventral premotor cortex have both visual and somatosensory receptor fields centered upon the arms, face, neck, and torso. And likewise, Graziano & Gross report that 20-30% of cells in area 7b of the posterior parietal cortex, and 24% of cells in the putamen, have similar properties (Graziano & Gross, 1994). Broadly consistent results have been produced in both neuropsychological (see footnote 5) and psychophysical studies (see footnote 6).

[8] So at the single neuron level Iriki et al. (1996) putatively found an extension of receptor fields right to the limit of the functional range of an actively used tool. At the neuropsychological level, there is an increased distance of crossmodal extinction effects to the tip of an actively used tool (Farnè & Làdavas, 2000; Farnè et al., 2005a). And at the behavioral level, visual distracters placed at the tip of an actively used tool have just as great a crossmodal effect on the detection of tactile stimuli as visual distracters from LEDs on the subjects' hands (Spence et al., 2004).

[9] In fact the neuropsychological data, at least, clearly point to a modular organization of peripersonal spatial representation (Farnè et al., 2005b; also see Legrand et al., 2007, section 8 for discussion).

space with their bodies as a whole. So does not *this* require a *representation* of the body *as a whole*? Not necessarily: At bottom it requires the capacity to execute complex transformations. In particular the system needs a mechanism to perform at least three functions: sensory-sensory transformation, sensory-motor transformation and motor-sensory transformation. Sensory-sensory transformation would instantiate a solution to what Pouget et al. (2002) call a 'recoding problem'. Different sensory modalities providing information encoded in different frames of reference (e.g. centered on the retina, head, arm, torso, or hand) do not use the same encoding. The task is to integrate sensory information in a way that enables the system to usefully track the relevant spatial properties. In order to achieve this end the signal processing must be *holistic*, which is to say that the only way that a system could usefully combine sensory signals from different modes would be through systematic *mutual modulation*, rather than merely (say) summing the inputs. Essentially, the *integration* of various modes of sensory input must be *non-linear*. A further difficulty is posed by our second desired function, sensory-motor transformation. Here the output achieved from the aforementioned non-linear combination must be a *linear* series of motor outputs, the sum of which should result in successful goal directed behavior (Pouget & Snyder, 2000; Pouget et al., 2002). This challenge, viz. sensory integration to sensorimotor transformation, is often called the 'kinematics problem'. A third and final issue points to the necessity of our third desired function, motor-sensory transformation. The generation of appropriate motor commands must also control for the specific application of forces required to achieve the specific movement trajectory determined by the solution of the kinematics problem. This challenge (viz. modulating the amplitude of the motor command signal in sympathy with the mass, load and joint torques of the relevant effectors) is often called the 'the dynamics problem' (Pouget & Snyder, 2000). What is effectively required here is a prediction of the *sensory consequences* of a particular set of motor commands to enable timely control, and thus involves transformations from motor to sensory coordinates (Wolpert & Ghahramani, 2000; Desmurget & Grafton, 2000; Pouget et al., 2002).

It seems that these tasks can be achieved by multiple coupled neural nets, dubbed as *recurrent basis function networks* (Pouget & Snyder, 2000; Pouget et al., 2002). By implementing basis functions (to enable the systematic mutual modulation of input signals) and recurrently feeding-back transformed signals, these networks can combine and recode various incoming sensory inputs (solving the recoding problem), transform non-linear sensory inputs into linear motor outputs (solving the kinematics problem), and transform linear motor commands into non-linear mock sensory signals, allowing prediction of their likely sensory consequences (solving the dynamics problem). Note that the crucial difficulty in this task is dealing with the multiplicity of reference frames. Note further that the multifunctionality provided by the architecture described would enable the system to seamlessly integrate and coordinate various multisensory body-part centred representations into linear output coordinates potentially coded in *any frame of reference available to the system* (Pouget et al. 2002, 746).

I submit that the *flexibility* of these networks might enable the crucial coupling and coordination of local representations, finessing any need for a fully articulate internal model of the body as a whole. For as and when these tasks are achieved each body-part representation might function as a dynamic model of the part it represents, constrained by the dynamics of adjacent parts as and when required. This leaves us with a theoretical choice. Either we assert that the mutual attunement of these local representations merely describes the internal workings of the global modeling process. Or we assert that the inherent flexibility required testifies to the fact that a global model is unnecessary.

I believe we ought to favor the latter on the grounds of parsimony. In either case, that which is internally represented must be attuned to the constraints posed by the synergetic unity of the actual body, for fear of being redundant. Since the system can encode, integrate, and transform the relevant relationships as and when needed, it can thereby rely upon local attunement, *without* representing unity as such. By using such a cheap and simple strategy, the system can get by (perhaps more efficiently) by merely representing parts, rather than explicitly representing bodily structure as a whole.

Now, let us move on to a similar problem and proposed solution at the personal level of bodily experience. In the next subsection, I suggest that we rarely (if ever) *attend* to our body as a whole. I introduce an attentional model on which the spatial orientation of parts is determined individually and related *ad hoc*. And again I suggest that the unity and stability of the body finesses any need for an internal representation of the body as whole.

2.2 The Personal Level

I take it as a datum that one never *sees* one's whole body at once; at most one sees a side. Even if by a clever arrangement of mirrors one were to see one's body from each and every angle, what would be seen would be a series of sides, from which one might *infer* the whole, while not actually seeing the whole itself all at once. Similarly, in attention to touch or pressure, flutter, itch, pain and so forth, I suggest that one can only *focus* on a particular body part or location. And when judging the static position or dynamic movement of one's limbs, one only *focuses* on this leg or that arm in this or that position, rather than the global configuration of the body.

Much in this vein, Marcel Kinsbourne (1995) proposed that bodily experience arises from *selective attention* to somatosensory input. More specifically, he hypothesized that bodily experience is enabled and modulated by the reciprocal balance of activity in opposing cortical networks processing contra-lateral sensory input; that conscious representations of the body are dynamic and fast decaying, requiring constant re-updating by selective attention; and that selective attention to individual body parts determines their spatial orientation independently and relates them to one another *ad hoc*, on structural principles.

As an illustration of the model, he proposed an interpretation of Lackner's vibrotactile illusions. In an intriguing paradigm Lackner used an electro-magnetic physiotherapy vibrator to induce illusory stretching of the biceps or triceps, known since as a vibrotactile illusion (Lackner, 1988; Lackner & Dizio, 1984; Lackner & Dizio, 1992). In one study this illusory stretching not only made subjects believe that their limb had moved, but also caused them to believe that the body part in contact with the limb (e.g. nose, top of head, waist) had stretched or depressed (Lackner & DiZio, 1984). For example, when subjects stood with a finger upon their head, triceps vibration induced the perceptual belief that their finger had entered their cranium or that their head had been forced into their trunk. Kinsbourne suggests the following lesson from these studies:

> One learns that the sense of joint position counts for little ... If a veridical representation (image) of the body exists in the brain, this evidently does not preclude people from readily experiencing their bodies in physically improbable or even impossible ways. This type of observation is more readily accommodated by the view that the representations of separate body parts are separately referred to their spatial locations and then related to each

> other than that an articulated image of the body is adjusted on an ongoing basis to reflect changing sensory input.
> (Kinsbourne, 1995, p. 215)

One does not want to make *too* strong a claim here. For instance, it would be hard to claim that one never *experiences* the body as whole. Indeed there does seem to be some rationale for claiming that the body *is* experienced as whole, in the context of making sense of attentional focus as a figure-ground relation. Thus as I perceive my arm in station, a non-perceptual experience of my body as a whole (both the relative locations of my limbs and the comportment of my torso) provides a background *attentional field* that structures the very sense of position that I attend to. As I attend to my arm in movement, a non-perceptual experience of my body's synergetic movements provides implicit structure to my focal kinesthetic experience (through attentively recessive joint-positional and postural senses).[10]

A mutual relationship between focus and periphery is crucial to characterizing the spatial phenomenology of bodily experience. Such an insight, however, need not lead us to postulate an internal representation of the body as a whole. As Kinsbourne notes in a later paper:

> 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 internalize all the body information all the time just in case some part of it becomes relevant.
> (Kinsbourne, 2002, p. 23)

On this view, the positing of a global *neural* representation of the body might be wrongheaded, for the body itself might actually function "as its own best representation" (Brooks, 1991). This kind of claim is similar to one made in reviews of the visual cognition literature. There is a well documented phenomenon known as 'change blindness', which suggests that we encode less information about the visual environment than it might seem, relying heavily on our capacities to access that information as and when needed (for some debate on this, see the collected papers in Noe (2002)). For instance, if you interpose masks between two consecutive images of largely the same scene, or visual distracters such as "mudsplashes" onto a continuously presented scene, subjects will often fail to notice (sometimes rather drastic) changes made.

Now in fact change blindness is *also* a phenomenon of *tactile* perception, as found in the work of Alberto Gallace and colleagues (Gallace et al., 2007). One contrast here is that tactile change blindness only requires the manipulation of very simple vibrotactile stimuli, as opposed to the usually rather complex perceptual scenes used in visual demonstrations. Nevertheless, just as in the visual modality, subjects are more likely to not report a change when there is one than to report a change when there is none.[11] In light of this, Kinsbourne's

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[10] See Gallagher (2003) for the distrinction between perceptual and non-perceptual experience of the body.

[11] This phenomenon has been demonstrated in audition (Eramudugolla, 2005), as well as in various crossmodal conditions, such as between vision and audition, and (importantly) between vision and touch (Gallace et al., 2006). Accordingly, in summarizing these and their own results, Gallace et al. point out that they are "consistent with the view that change blindness may reflect a more general multimodal/amodal mechanism (possibly related to the

basic idea seems compelling. For it might be that just as in vision, rather than encoding the entire domain in all its glorious detail, the system could employ a "minimal memory strategy" to exploit various stable features of that domain.[12] It might merely retrieve, integrate and amplify the relevant signals *ad hoc*, getting away with making implicit structural assumptions, instead of having an explicit internal representation of the body's overall structural layout modulated according to its occurrent overall disposition.

O'Shaugnessy (1995) adds further depth to this point when he distinguishes between three concepts of a "short term body image," and one of a "long term body image." For the short-term he discerns: an *alpha* body image – the occurrent perception of a body part in attentive focus; a *beta* body image – the occurrent spatial configuration of the body as a whole; and a *gamma* body image – the range of *potential perceptions* within the occurrent spatial configuration of the body as a whole. These he distinguishes from a *long term body image*, the abstract structural arrangement of the body as a whole. (Metaphorically speaking, "the 'metal' in which these [former] are cast" (O'Shaugnessy, 1995, p. 186)). Adopting his language, I propose that an *alpha* does not require an internal representation of a *beta* that constrains a *gamma*, which might in turn wholly determine a token *alpha.* The stability and synergetic unity of the actual body can function as a *long term body image* and provide reliable local constraints for a *gamma*, thus finessing any need for a *beta* representation.

So now the claim is that in both sub-personal spatial representation and personal level focal attention, the system could internally represent the body in a piecemeal fashion, in terms of *ad hoc* part-part relations, and lean upon the actual unity of the body.

But saying only this much is not quite satisfying: there is something of a lacuna that desperately needs filling. In particular, it is not yet clear what the relevant synergetic features of the actual body are, and what work they might do in constituting the intra-corporeal frame of reference which we set out as our concern early on. These are rather difficult issues, the full resolution of which will require a developmental story that cannot be told here for brevity's sake. Nevertheless in the final section, I aim to make steps towards preliminary answers. In doing so, I attempt to dissolve a puzzle concerning the organization of the spatial content of bodily experience.

3. Egocentric Frames of Reference and the Body

Egocentric frames of reference require spatial points of origin, from which other spatial locations can be referred. This is particularly easy to grasp in vision. Two eyes, front and equidistant from center on a normal human head, provide a point from which it can view the world as having relative points that are *here* rather than *there*, *near* rather than *far*, *left* rather than *right*, *in front* rather than *in back* and so forth. Nonetheless, accounting for the spatial structure of bodily experience in this way might seem problematic. It might seem that there is no obvious point of origin for, and thus seemingly no egocentricity to, an intra-corporeal frame of reference.

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awareness of spatial information), rather than a specific unimodal, underlying mechanism." (2007, p. 484).

[12] See Ballard et. al (1997) for the original suggestion of this as a general computational strategy.

The clearest articulation of this view comes from Bermudez (1998, 2005) who asserts that ‘egocentric questions’ concerning *distance* and *direction* do not make sense, either in the case of focal somatic proprioception or in attention to bodily sensations. He takes the ‘distance question’ to be roughly: Would a line between origin O and object *a* be shorter than one between O and object *b*? He takes the ‘direction question’ to be roughly: Would a line between origin O and the furthest object run through the nearest object? Each question makes reference to an original point that structures the egocentric location of the respective object. Furthermore, each question only makes sense if we include such a point of origin. If this is right, then the claim that bodily experience is egocentrically structured might be somewhat baffling. For when we are discerning spatial relations between two spatially distinct bodily experiences (objects *a* and *b*), it seems that “there is no privileged part of the body that counts as *me* for the purpose of discussing the spatial relations they bear to one another” (Bermudez, 2005, 209).

One need not be puzzled. There are at least two responses. The first concerns the fact that non-pathological humans, at least, are extraordinarily vision-orientated creatures: There are clear cases in which vision has an intermodal influence on bodily experience. Take, for instance, the so-called “rubber-hand” illusion, where subjects are visually presented with a rubber hand that is synchronously stroked with their own unseen hand. After a period of synchronous stroking, subjects relate such statements as, “I was feeling the touch where I saw the brush.” A typical explanation of this is that the synchronously seen and felt stroking produces an intermodal conflict that is resolved in favor of vision. Indeed, vision is deemed such a reliable cue to the system that spinal cord injury patients can continue to enjoy bodily experiences in the absence of *any* sensory input from below the neck. As Jonathon Cole reports:

> Though deprived of peripheral sensation several people told me of how they could feel their legs. One woman was convinced that she knew where her legs were in space – on her chair or in bed – and was surprised when I suggested that this might have been because she could see them and had a visual capture of a positional sense. Another “felt” touch on her leg when she saw her leg being touched, and only when she saw the touch, a clear visual capture of sensation homologous with the dummy hand experiments. (Cole, 2005, p. 316)

Therefore, a first response is this. It is certainly conceivable, and quite probably actually the case, that a *visuo*spatial image of the body provides a dominant egocentric frame of reference to bodily experience. We can conceptualize the structure of this egocentric space in terms of two key structural features of the body and the mobility of its parts. Firstly, the extent to which the visual profile of body parts can be or is generally reduced gives a basic phenomenological gradient between *here* and *there*. For instance, one can greatly reduce the visual profile of one’s feet, to a lesser extent one’s arm, and not at all one's ever-present nose (Gibson, 1969, pp. 114 – 121). Secondly, the visual field is not only constrained by the physical situation of visual apparatus, it is also *bounded* by the front-back asymmetry of the human body (Todes, 1963/2001).

I contend that, in virtue of these basic features of the body’s structure and mobility, there is a natural sense in which we might experience our feet as down there, or an itch on our nose as right here, or an insect bite on the bum as back there, and so forth.

However, Bermudez might retort that this does not really give an account of bodily experience *on its own terms*. He might claim, that (leaving behavioral demonstrations aside), the above analysis is only apt to characterize experience of the body in cases where proximal information is pathologically absent, such as the spinal cord injury patients mentioned, or rarer cases of solely sensory deafferentation.[13] Indeed, the following quote is suggestive:

> The frame of reference for their bodily awareness does indeed have an origin—the eyes—and for this reason both of the two questions mentioned make perfect sense. But this is not at all the way in which we experience our bodies *from a first-person perspective* (Bermudez 2005, p. 310) [14]

I am not sure that a careful investigation of non-pathological focal attention to the body will actually support this claim. But I want to leave that question aside here and provide a different kind of response. To narrow down the crucial explanatory target I think it will help to introduce a hypothetical character congenitally deprived of vision, olfaction, audition, and even gustation: 'Touchy'. The only sensory information available to Touchy is available exclusively through the cluster of senses I associated with the term bodily experience at the beginning – through somatic proprioception, somatosensation and perhaps certain spatially distinct visceral sensations. I contend that Touchy still enjoys spatial phenomenology. Furthermore, I contend that there is a natural sense in which she can focally experience her feet as *down there*, and similarly experience other parts of her body in egocentric terms.

In order to argue this I need to provide a less visuocentric account of egocentric space. Two points before I proceed. I will not explore how multimodally modulated experience of the body stands constitutively in relation to the wholly non-visual account that follows. That complex and interesting issue deserves separate treatment. Secondly, I admit the following is largely speculative. Nevertheless, it has the virtue of being a neat synthesis of insights from preceding discussions.

A useful start is a tapered version of Gareth Evans's (1982, 1985) suggestion that the spatial content of perceptual experience is constituted by direct ties between sensory and motor capacities. Consider the following statements: "...we must say that having the [spatial] perceptual information at least partly consists in being disposed to do various things" (Evans, 1985, p. 383); "…*up*, or *down*, *to the right* or *to the left*, *in front* or *behind*, or *over there*. It is clear that these terms are *egocentric* terms […] these egocentric terms derive their meaning from their (complicated) connections with the actions of the subject" (Evans, 1985, p. 384). I want to embrace this basic idea by elaborating upon and integrating material from previous parts of the paper.

First, the idea of a direct sensorimotor interface constituting egocentric content can be unpacked in terms of two kinds of action-oriented content, one kind at the sub-personal level and another at the personal level. Thus borrowing (and modifying) a distinction made in various ways (e.g. by Rick Grush, 2007; see also Clark, 2001) we can say that at the sub-personal level sensory information has egocentric spatial content in virtue of directly priming *detailed specifications for movement*; whereas at the personal level sensory information has

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[13] For the famous cases of Ian Waterman and G.L see Cole, 1995; Cole & Paillard, 1995.

[14] Of course, "we" is meant to refer to non-pathological humans and "their" is supposed to refer to relevantly inflicted pathological humans.

egocentric spatial content in virtue of priming the *selection of particular types of action*. We can further specify functional profiles in terms of the two mechanisms we spoke of in the last section. At the sub-personal level, the automatic and flexible interface between sensory and motor capacities enables the system to implement the control and guidance of movements. On the personal level, the play of selective attention across body parts enables the selection and ordering of targets for appropriate types of action.[15]

Second, motor capacities are importantly channeled through the overall structure and mobility of the actual body, which both enables and constrains the embodied agent in virtue of its actual part-part and part-whole relations. Now, there are a great many ways in which the body's interlocked structure sets constraints on movement dynamics. Some very simple and intuitive features of the human body in this regard are the lateral reflective symmetry of limb topology and the front-to-back asymmetry of limb motion. Here it is important to note that it is not just the interlocked structure of individual parts that set such constraints, but rather their global context. To capture this constraining relationship I would like to introduce the theoretical notion of a *structural affordance*, modifying a well-known term of Gibson's (1979). Here the affordance relation holds merely between brain and body, rather than between agent and environment.[16] From these bare bones we can provide a number of propositions that form the skeleton of a theory:

- A set of structural affordances is constituted by the range of capacities and limitations for movement that the structure and mobility of a particular embodiment affords.
- A given structural affordance is a mereological relation, where a part (or a set of interrelated parts) of the embodied system exhibits an affordance for the system as a whole, in the context of the system as a whole.
- Structural affordances do not actually have to be demonstrated, but the possibility of their demonstration at a given time is an important background condition of their instantiation.
- Structural affordances are highly fine-grained at the subpersonal level. They are processed as finely individuated possibilities for movement. They are reflected in the way that part-part relations are represented, and the way that relevant information is transformed in sympathy with synergetic relationships between these parts.
- Structural affordances are coarse grained at the personal level. They are presented as possibilities for various types of action. They are understood practically and they frame the spatial structure of the attentional figure-ground relationship.

One of the main motivations for introducing any theory or theoretical notion ought to be its explanatory utility. A running theme in our discussion has been that any account of the spatiality of bodily experience is crucially complicated by the fact that body parts are

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[15] Here I am assimilating something like Andy Clark's (2001) 'experience based selection' model of the functional role of conscious experience in guiding actions; see also Paillard (2005); Dijkerman and de Haan (2007).

[16] This should *not* be construed as a denial of affordance relations holding between agent and environment, or a denial of any interaction between such "agent-environmental" affordances and structural affordances. The relationship between these two kinds of affordance is an under-researched area, and of course it has not yet been researched at all in these terms. This is a real shame; for intuitively, understanding the interaction between structural affordances and agent-environmental affordances is crucial in understanding what it is to be a physical agent.

differentially mobile, and bound to one another. A structural affordance theory of bodily experience aims to capture the mutually constraining and enabling relationships that hold between parts of the body, and the constitution of the whole in virtue of these relationships. The crucial claims are as follows: Structural affordances provide basic ordering principles that serve as constraints for the attunement of body-part centered models. Assuming that focal bodily experience is itself framed by the peripheral, the theory describes said ‘periphery’ as the non-perceptually experienced structure of the body and the constrained mobility of its parts as bound up with one another. This structure and mobility is first and foremost understood practically, although it may (perhaps derivatively) be understood propositionally. It is the agent’s practical understanding of its structural affordances that provide the basic constitutive elements of its spatial phenomenology.

Unfortunately, there is only space to suggest the relationship between personal level content and sub-personal mechanisms in the present case. The suggestion is that on the sub-personal level, proper function in the guidance and control of coordinated action enables the agent to have a personal level practical understanding of its structural affordances. This yields two hypotheses: One, that the verisimilitude of the agent’s practical understanding is determined by the proper function and efficiency of attuned sensorimotor transformations. And two, that the spatial determinacy of focal bodily experience is a function of the agent’s capacity to accurately execute actions toward that location.

With these notes in hand let us return to the Bermudez quote we had earlier on this section. Remember, according to Bermudez, “...there is no privileged part of the body that counts as *me* for the purpose of discussing the spatial relations [that body parts and/or bodily locations] bear to one another” (Bermudez, 2005, 209). If we focus on the relationship between parts and wholes in the phenomenology, as seems crucial, it is not clear that we need to privilege any particular part of the body as the subject. Rather, the subject would more plausibly be the whole itself. This might be contentious, but no more than the alternative requirement. So let us leave aside the complex issue of the relationship between egocentric spatial content and first-person content and consider what we are then left with. We are left with a more modest notion such as this: “... the ‘ego’ of an ‘egocentric’ reference frame is whatever is the body part and its indexical location that stands in an intentional relation to a target, and this can be at multiple points simultaneously.” (Marcel, 2003, p. 84). This latter locution meshes neatly with both the selective attentional approach to bodily experience we have adopted, and the claim that its spatial content is action-oriented content. However, this requires a little qualification, and a little clarification.

To qualify: The “intentional relation” is that which a motor goal state bears to its satisfaction conditions. Evidently a range of goal states might be primed without being realized, just as the motor capacities themselves need not actually be realized. While it might make sense to think of multiple points of origin on the subpersonal level (cf. section 2.1) this does not necessarily hold for personal level content. Potentially, there might well be multiple spatial points of origin, but for the conscious agent occurrent points would be tied to particular actions primed by selective attention.

To clarify: It might seem that this amounts to a fragmentation of egocentric space into a multiplicity of body-part centered spatial points of origin. This would only be a problem if each attended part were a spatial point of origin for a *separate* behavioral space. Given the interlocked structure of the body, it follows naturally that the agent exists in a unified behavioural space and thus experiences a unified egocentric space. [17]

We are now in a position to say something about Touchy. Despite the difficulties in conceiving of such wholly non-visual egocentricity, I hope that it is now natural to think that Touchy experiences an itch as (say) *back there*, in virtue of the front-back asymmetry of her bodily structure. She might experience her left foot *in front of* her right as she stands, in virtue of how each constrains the other's movement possibilities. She might never even try to reach her feet with her hands while standing because she experiences the distance as simply *too far*. But "Touchy 2," of similar height and limb proportions, yet significantly more flexible, might deem her feet as *close enough to reach* at any time she attends to them.

Conclusion

To sum up: In the first section I noted the general complexity of bodily experience, and stated my target as the spatial content of bodily experience. In the second section, I suggested that we only internally represent part-part relations explicitly, and that part-whole relations are enabled through close tuning to the system's actual embodiment. In the final section I made more of the mechanisms mentioned in part two (and the actual body involving part-whole relations) in order to give an account of how the intra-corporeal frame of reference might be egocentrically structured. I have suggested that focal somatic attention is structured egocentrically, in virtue of being constituted by action-oriented representations that have an action-type specifying content. The motor capacities expressed by such content are constrained and enabled by the agent's practical understanding of its structural affordances. In this way the embodied agent's practical understanding of its structure and mobility constitutes its intra-corporeal frame of reference.

References

Ballard, D., Hayhoe, M., Pook, P., & Rao, R. (1997). Deictic codes for the embodiment of cognition. *Behavioral and Brain Sciences*, *20*, 723-767.

Bermudez, J. L. (1998). *The paradox of self consciousness.* Cambridge Mass., London: MIT Press.

Bermudez, J. L. (2005). The phenomenology of bodily awareness. In D. Woodruff Smith, & A. Thomasson (Eds.), *Phenomenology and philosophy of mind* (pp. 295-316). Oxford: Clarendon Press.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature , 391*, 756.

Brooks, R. (1991). Intelligence without representation. *Artificial Intelligence*, *47*, 139-159.

Clark, A. (2001). Visual experience and motor action: Are the bonds too tight? *Philosophical Review , 110* (4), 495-519.

Coello, Y., & Delevoye-Turrel, Y. (2007). Embodiment, spatial categorisation and action. *Consciousness and Cognition , 16*, 667-683.

[17] In many ways this is not a new point. For example, Gareth Evans made a similar point in the eighties (Evans, 1985).

Cole, J. (1995). *Pride and a daily marathon.* Cambridge, Mass.: MIT Press.

Cole, J. (2005). On the relation of the body image to sensation and its absence. In H. De Preester, & V. Knockaert (Eds.), *Body image and body schema: Interdisciplinary perspectives on the body* (pp. 311-328). John Benjamins.

Cole, J., & Paillard, J. (1995). Living without touch and peripheral information about body position and movement: Studies with deafferented subjects. In J. L. Bermudez, A. Marcel, & N. Eilan (Eds.), *The body and the self* (pp. 245-266). Cambridge, Mass: MIT Press.

Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews Neuroscience , 3*, 655-666.

Craig, A. D. (2003). Interoception: The sense of the physiological condition of the body. *Current Opinion in Neurobiology , 13*, 500-505.

Desmurget, M., & Grafton, S. (2000). Forward modeling allows feedback control for fast reaching movements. *Trends in Cognitive Sciences , 11* (4), 423–31.

de Vignemont, F., Tsakiris, M., & Haggard, P. (2006). Body mereology. In G. Knoblich, I. M. Thornton, M. Grosjean, & M. Shiffrar (Eds.), *Human body perception from the inside out* (pp. 147-170). New York: Oxford University Press.

Dijkerman, H. C., & de Haan, E. H. (2007). Somatosensory processes subserving perception and action. *Behavioural and Brain Sciences , 30*, 189-239.

di Pellegrino, G., Làdavas, E., & Farnè, A. (1997). Seeing where your hands are. *Nature, 380*, 730.

Eilan, N., Marcel, A., & Bermudez, J. L. (1995). Self-consciousness and the body: An interdisciplinary introduction. In J. L. Bermudez, A. Marcel, & N. Eilan (Eds.), *The Body and the self* (pp. 1-29). Cambridge Mass.: MIT Press.

Eramudugolla, R., Irvine, D. R., McAnally, K. I., Martin, R. L., & Mattingley, J. B. (2005). Directed attention eliminates “Change Deafness” in complex auditory scenes. *Current Biology , 15*, 1108-1113.

Evans, G. (1982). *The varieties of reference.* Oxford: Clarendon Press.

Evans, G. (1985). Molyneux's Question. In *The collected papers of Gareth Evans.* London: Oxford University Press.

Farnè, A., & Làdavas, E. (2000). Dynamic size-change of hand peripersonal space following tool use. *Neuroreport , 85*, 1645–1649.

Farnè, A., Bonifazi, S., & Làdavas, E. (2005a). The role played by tool use and tool length in the plastic elongation of peri-hand space: A single-case study. *Cognitive Neuropsychology , 22* (3/4), 408-418.

Farnè, A., Demattè, M. L., & Làdavas, E. (2005b). Neuropsychological evidence of modular organization of the near peripersonal space. *Neurology , 65*, 1754–1758.

Fogassi, L., Gallese, V., Fadiga, L., Luppino, G., Matelli, M., & Rizzolati, G. (1996). Coding of peripersonal space in inferior premotor cortex (Area F4). *Journal of Neurophysiology , 76* (1), 141-157.

Gallace, A., Tan, H. Z., & Spence, C. (2006). The failure to detect tactile change: A tactile analogue of change blindness. *Psychonomic Bulletin & Review , 13*, 300-303.

Gallagher, S. (2003). Bodily self-awareness and object-perception. Theoria et Historia Scientiarum: International Journal for Interdisciplinary Studies 7: 53-68

Gibson, J. J. (1979). *The ecological approach to visual perception.* Boston: Houghton Mifflin.

Graziano, M. S., & Gross, C. G. (1994). The representation of extrapersonal space: A possible role for bimodal, visual-tactile neurons. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1021-1034). Cambridge Mass.: MIT Press.

Grush, R. (2007). Skill theory v.2.0: Dispositions, emulation, and spatial perception. *Synthese, 159* (3), 389-416.

Haggard, P., Taylor-Clarke, M., & Kennett, S. (2003). Tactile perception, cortical representation and the bodily self. *Current Biology , 13*, R170–R173.

Holmes, N. P., & Spence, C. (2004). The body schema and multi-sensory representations of peripersonal space. *Cognitive Processes , 5*, 94-105.

Iriki, A., Tanaka, M., & Iwamura, Y. (1996). Coding of modified body schema during tool use by macaque postcentral neurones. *Neuroreport , 7*, 2325–2330.

Kinsbourne, M. (1995). Awareness of one's own body: An attentional theory of its nature, development, and brain basis. In J. Bermudez, A. Marcel, & N. Eilan (Eds.), *The body and the self* (pp. 205-223). MIT Press.

Kinsbourne, M. (2002). The brain and body awareness. In T. Pruzinsky & T. Cash (Eds.), *Body images: A handbook of theory, research, and clinical practice* (pp. 22-39). New York: Guilford.

Lackner, J. R. (1988). Some proprioceptive influences on the perceptual representation of body shape and orientation. *Brain , 111* (2), 281-297.

Lackner, J. R., & DiZio, P. (1984). Some efferent and somatosensory influences on body orientation and oculomotor control. In L. Spillman, & B. R. Wooten (Eds.), *Sensory experience, adaptation and perception.* Hillsdale, NJ: Erlbaum.

Lackner, J. R., & DiZio, P. (1992). Gravitoinertial force level affects the appreciation of limb position during muscle vibration. *Brain Research , 592* (1-2), 175-180.

Làdavas, E. (2002). Functional and dynamic properties of visual peripersonal space. *Trends in Cognitive Science , 6*, 17–22.

Làdavas, E., Farnè, A., Zeloni, G., & di Pellegrino, G. (2000). Seeing or not seeing where your hands are. *Experimental Brain Research , 131*, 458–467.

Legrand, D., Brozzoli, C., Rosetti, Y., & Farne, A. (2007). Close to me: multisensory space representations for action and pre-reflexive consciousness of oneself-in-the-world. *Consciousness and Cognition , 16* (3), 687-699.

Maravita, A., & Iriki, A. (2004). Tools for the body(schema). *Trends in Cognitive Sciences , 8* (2), 79-86.

Marcel, A.J. (2003). The Sense of Agency: Awareness and Ownership of Action. In J. Roessler & N. Eilan (Eds.) *Agency and Self-awareness: Issues in Philosophy and Psychology* (pp. 48 – 93) (2003) Oxford University Press.

Mattingley, J. B., Driver, J., Beschin, N., & Robertson, I. H. (1997). Attentional competition between modalities: Extinction between touch and vision after right hemisphere damage. *Neuropsychologia , 35*, 867–880.

Noe, A. (ed.) (2002). *Is the visual world a grand illusion?.* Thorverton, UK: Imprint Academic.

O'Shaughnessy, B. (1995). Proprioception and the body image. In J. L. Bermudez, A. Marcel, & N. Eilan (Eds.), *The body and self* (pp. 175-205). Cambridge, Mass.: MIT Press.

Paillard, J. (2005). Vectorial versus configural encoding of body space: A neural basis for a distinction between body schema and body image. In H. De Preester, & V. Knockaert (Eds.), *Body image and body schema: Interdisciplinary perspectives on the body* (pp. 89-111). John Benjamins.

Pouget, A., & Sejnowski, T. (1997). Spatial transformations in the parietal cortex using basis functions. *Journal of Cognitive Neuroscience, 9* (2), 222-237.

Pouget, A., & Snyder, L. H. (2000). Computational approaches to sensorimotor transformations. *Nature Neuroscience, 3*, 1192-1198.

Spence, C., Pavani, F., Maravita, A., & Holmes, N. P. (2004). Multisensory contributions to the 3-D representation of visuotactile peripersonal space in humans: Evidence from the crossmodal congruency task. *Journal of Physiology , 98* (1-3), 171-189.

Todes, S. (1963/2001). *Body and world.* Cambridge, Mass.: MIT Press.

Tononi, G., & Edelman, G.M. (1998). Consciousness and the integration of information in the brain. *Advances in Neurology*, *77*, 245-279.

Wolpert, D. M., & Ghahramani, Z. (2000). Computational principles of movement Neuroscience. *Nature Neuroscience, 3*, 1212-1217.