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Since this is a colloquium on phenomenological and experimental approaches to cognition I'd like to set up the problem I want to address in terms of two of the different strands that we find in Merleau-Ponty's thinking about the phenomenology of the body. One of these strands is profoundly insightful. The other one, however, seems to me to be lacking in plausibility - or rather, to put it less confrontationally and more in keeping with the spirit of the colloquium, the second strand seems to stand in the way of there being a certain type of fruitful interaction between phenomenological and experimental approaches to cognition. As far as I can see (and I'm very much open to correction at this point) Merleau- Ponty was of the opinion that they came as a package. What I would like to do in this short presentation is sketch out a line of thought that prises them apart.

The first line of thought is summarised in Merleau-Ponty's concise comment that "The outline of my body is a frontier which ordinary spatial relations to do not cross" (Merleau-Ponty 1965/1968, p. 98). The essential point he makes is that there is a discontinuity between the experienced spatiality of the physical world and the experienced spatiality of the body - more precisely, of the lived body, of the body as we might experience it from the inside. This first line of thought seems to me to be phenomenological, both in the technical sense and in the sense in which the term is used within contemporary analytic philosophy - that is to say, it characterises the way in which things are given to the experiencing and acting subject. In the second line of thought, in contrast, we find Merleau-Ponty moving from phenomenology to ontology. The basic idea

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here is that the body is not an object - or, more precisely, that the lived body, the experienced body, cannot be understood as an object on a par with other objects in the external world.

It will be helpful, I think, if we trace the interplay between these two lines of thought in a single example. I'd like to concentrate on Merleau-Ponty's discussion of the patient Schneider in the long chapter entitled 'The Spatiality of One's Own Body and Motility'. He is discussing a patient suffering from what he terms psychic blindness - the essence of the disorder being an inability to carry out what he (Merleau-Ponty) calls abstract movements, such as moving his arms and legs to order, naming and pointing to body-parts, when his eyes are shut. He points out that there are certain movements that this patient is perfectly capable of making. Some of these are what we might call body-relative reactions. Here is an example.

> A patient of the kind discussed above, when stung by a mosquito, does not need to look for the place where he has been stung. He finds it straight away, because for him there is no question of locating it in relation to axes of coordinates in objective space, but of reaching with his phenomenal hand a certain painful spot on his phenomenal body, and because between the hand as a scratching potentiality and the place stung as a spot to be scratched a directly experienced relationship is presented in the natural system of one's own body. (Merleau-Ponty 1965/1968, pp. 105-106)

It seems to me that this description of what is going on is quite right. When one performs a simple body-relative action such as scratching an mosquito sting there is indeed no question of locating the sting on some sort of objective coordinate system, working out where one's hand is on the same coordinate system and then plotting a path between the two locations. The locations of both hand and sting are given in body-relative space (and I shall have more to say later about how this should be understood).

But Merleau-Ponty then goes on to make some much stronger claims about the patient in question:

> The whole operation takes place in the domain of the phenomenal; it does not run through the objective world, and only the spectator, who lends his objective representation of the living body to the acting subject, can believe that the sting is perceived, that the hand moves in objective space, and consequently find it odd that the same subject can fail in experiments requiring him to point things out. (Merleau- Ponty 1965/1968, p. 106)

These basic ideas then get generalised into a global distinction between the phenomenal body and the objective body. A few lines further on he writes:

> It is never our objective body that we move, but our phenomenal body, and there is no mystery in that, since our body, as the potentiality of this or that part of the world, surges towards objects to be grasped and perceives them. (Merleau-Ponty 1965/1968, p. 106)

The distinction between the phenomenal body and the objective body plays an important role in *The Phenomenology of Perception.* The phenomenal body is supposed to play a foundational role in the very constitution of the objective world. Here is a representative passage:

> The body is not one more among external objects. It is neither tangible nor visible in so far as it is that which sees and touches. The body, therefore, is not one more among external objects, with the peculiarity of always being there. If it is permanent, the permanence is absolute and is the ground for the relative permanence of disappearing objects, real objects. The presence and absence of external objects are only variations within a field of primordial presence, a perceptual domain over which my body exercises power. Not only is the permanence of my body not a particular case of the permanence of external objects in the world, but the second cannot be understood except through the first: not only is the perspective of my body not a particular case of that of objects, but furthermore the presentation of objects in perspective cannot be understood except through the resistance of my body to all variations in perspective. (Merleau-Ponty 1965-1968, p. 92)

I don't want to make any strong claims about what is going on here. What I would like to stress, however, is a conditional claim, namely, that *if* we accept Merleau-Ponty's distinction between the phenomenal body and the objective body, then it looks as if there will be very little scope for scientific study of the interesting and important aspects of bodily experience. Science, whether cognitive science, empirical psychology or neurophysiology, can only inform us about the objective body. It can have nothing to say about the phenomenal body.

What I would like to do in this paper is to present a way of thinking about the spatiality of bodily awareness that tries to do justice to the points that Merleau-Ponty stressed about the distinctive phenomenology of the experienced body - the fundamental differences between that in which we experience our own bodies and the ways in which we experience non-bodily physical objects. I'll be stressing that bodily awareness is fundamentally non-Cartesian - by which I mean that the frame of reference of bodily perception is not a Cartesian frame of reference. I'll sketch out a non-Cartesian alternative. At the end of paper I'll illustrate by example how this approach to the experienced spatiality of somatic proprioception can be integrated with contemporary work on the psychology of motor control.

The experienced spatiality of somatic proprioception

It is clear that the bodily states that form the objects of proprioception are proprioperceived in a way that locates them within a space bounded by the limits of the body. In disorders such as phantom limb or neglect bodily states are located within the bounds of the *experienced* body, even though the experienced body fails to map exactly onto the real body. The first question that arises in thinking about proprioceptive content, therefore, is how we should think about the frame of reference that determines how proprioceptive states are located within body-relative space.

Almost all discussions of the spatiality of proprioception have presupposed that exteroceptive perception, proprioception and the intentions controlling basic bodily actions must all have spatial contents coded on comparable frames of reference. This an obvious assumption, given that action clearly requires integrating motor intentions and commands with perceptual information and proprioceptive information. Since the spatial locations of perceived objects and objects featuring in the contents of intentions are given relative to axes whose origin lies in the body - in *egocentric frames of references* - it is natural to suggest that the axes which determine particular proprioceptive frames of reference are centred on particular body-parts, just as are the axes determining the frames of reference for perceptual content and basic intentions.

Despite its appealing economy, however, this account is ultimately unacceptable, because of a fundamental disanalogy between the *bodily space* of proprioception and the egocentric space of perception and action. In the case of vision or exteroceptive touch there is a perceptual field bounded in a way that determines a particular point as its origin. Since the visual field is essentially the solid angle of light picked up by the visual system the origin of the visual field is the apex of that solid angle. Similarly, the origin of the frame of reference for exploratory touch could be a point in the centre of the palm of the relevant hand. But somatic proprioception is not like this at all. It is not clear what possible reason there could be for offering one part of the body as the origin of the proprioceptive frame of reference.

There are certain spatial notions that are not applicable to somatic proprioception. For any two objects that are visually perceived it makes obvious sense to ask both of the following questions:

(a) which of these two objects is further away?

(b) do these objects lie in the same direction?

The possibility of asking and answering these questions is closely bound up with the fact that visual perception has an origin-based frame of reference.

Question (a) basically asks whether a line between the origin and one object would be longer or shorter than a corresponding line between the origin and the other object. Question (b) is just the question whether, if a line were drawn from the origin to the object that is furthest away, it would pass through the nearer object.

Neither question makes sense with respect to proprioception. One cannot ask whether this proprioceptively detected hand movement is farther away than that itch, nor whether this pain is in the same direction as that pain. What I am really asking when I ask which of two objects is further away is which of the two objects is further away from me, and a similar tacit self-reference is included when I ask whether two objects are in the same direction. But through somatic proprioception one learns about events taking place within the confines of the body, and there is no privileged part of the body that counts as *me* for the purpose of discussing the spatial relations they bear to each other.

To get a firmer grip on the distinctiveness of the frame of reference one need only contrast the bodily experience of normal subjects with that of completely deafferented subjects, such as Jonathan Cole's patient IW. The moment-to-moment information about their bodies that deafferented patients possess is almost exclusively derived from vision. Their awareness of their own body is continuous with their experience of the extra-bodily world. They are aware of their bodies only from the same third-person person perspective that they have on non-bodily physical objects. 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.*

The conclusion to draw from this is that the spatial content of somatic proprioception cannot be specified within a Cartesian frame of reference that takes the form of axes centred on an origin. So, if somatic proprioception is to have a content at all, that content must be understood in a fundamentally different way. In the next section I sketch out a way of understanding the frame of reference of somatic proprioception that fully accounts for the distinctiveness of the experienced spatiality of the body.

The spatial content of somatic proprioception

An account of spatial content must provide criteria for sameness of place. In the case of somatic proprioception this means criteria for sameness of bodily location. But there are several different forms of criteria for sameness of bodily location. Consider the following two situations:

(i) I have a pain at a point in my right ankle when I am standing up and my right foot is resting on the ground in front of me.
(ii) I have a pain at the same point in my ankle when I am sitting down and my right ankle is resting on my left knee.

According to one set of criteria the pain is in the same bodily location in (i) and (ii) - that is to say, it is at a given point in my right ankle According to another set of criteria, however, the pain is in different bodily locations in (i) and (ii), because my ankle has moved relative to other body-parts. Let me term these *A-location* and *B-location* respectively. Note, moreover, that B-location is independent of the actual location of the pain in ‘objective space’. The B-location of the pain in (ii) would be the same if I happened to be sitting in the same posture five feet to the left.

Both A-location and B-location need to be specified relative to a frame of reference. In thinking about this we need to bear in mind that the human body has both moveable and (relatively) immoveable body parts. On a large scale the human body can be viewed as an immoveable torso to which are appended moveable limbs - the head, arms and legs. Within the moveable limbs there are small-scale body-parts that can be directly moved in response to the will (such as the fingers, the toes and the lower jaw) and others which cannot (such as the base of the skull). A joint is a body-part that affords the possibility of moving a further body-part, such as the neck, the elbow or the ankle. In the human body, a relatively immoveable torso is linked by joints to 5 moveable limbs (the head, two legs and two arms), each of which is further segmented by means of further joints. These joints provide the fixed points in terms of which the particular A-location and B-location of individual body-parts at a time can be given.

A particular bodily A-location is specified relative to the joints that bound the body-part within which it is located. A particular point in the forearm is specified relative to the elbow and the wrist. It will be the point that lies on the surface of the skin at such-and-such a distance and direction from the wrist and such and such a distance and direction from the elbow. This mode of determining A-location secures the defining feature of A-location, which is that a given point within a given body-part will have the same A-location irrespective of how the body as a whole moves, or of how the relevant body-part moves relative to other body-parts. The A-location of a given point within a given body-part will remain constant in both those movements, because neither of those movements will bring about any changes in its distance and direction from the relevant joints.

The general model for identifying B-locations is as follows. A particular constant A-location is determined relative to the joints that bound the body-part within which it falls. That A-location will either fall within the (relatively) immoveable torso or it will fall within a moveable limb. If it falls within the (relatively) immoveable torso then its B-location will also be fixed relative to the joints that bound the torso (neck, shoulders and leg sockets) - that is to say, A-location and B-location will coincide. If, however, that A-location falls within a moveable limb, then its B-location will be fixed recursively relative to the joints that lie between it and the immoveable torso. The B-location will be specified in terms of the angles of the joints that lie between it and the immovable torso. Some of these joint angles will be rotational (as with the elbow joint, for example). Others will be translational (as with the middle finger joint).

This way of specifying A-location and B-location seems to capture certain important elements in the phenomenology of bodily awareness.

— We do not experience peripheral body parts in isolation, but rather as attached to other body-parts. Part of what it is to experience my hand as being located at a certain place is to experience that disposition of arm-segments in virtue of which it is at that place.
— It is part of the phenomenology of bodily awareness that sensations are always experienced within the limits of the body. This is exactly what one would expect given the coding in terms of A-location and B-location. There are no points in (non-pathological) body-space that do not fall within the body.
— Although B-location is specified recursively in terms of the series of joint angles between a given A-location and the immovable torso, the torso does not function as the origin of a Cartesian frame of reference.

The spatiality of bodily awareness and the control of action

In the previous section I suggested that the spatial content of bodily awareness is fundamentally different from the spatial content of visual and other forms of exteroceptive awareness. The obvious question that this raises is how proprioceptive content features in the control of action, given that action requires the contribution and integration of proprioceptive and exteroceptive awareness. What I will try to do in this final section is explain how the account I have offered of the spatial content of somatic proprioception fits in with what is currently known about motor control.

Any planned motor movement directed towards an extra-bodily object requires two basic types of information:

(1) Information about the position of the target relative to the body
(2) Information about the starting position of the relevant limb (the hand in the case of a reaching movement)

Recent work, based on the study of trajectory errors and the velocity profiles of hand movements, suggests that both types of information are coded in extrinsic coordinates in a frame of reference centred on the hand (Ghez et al. 2000). Intended reaching movements are coded in terms of hand-centred vectors, rather than in terms of the complex muscle forces and joint torques required for the action to be successfully carried out. It is known, for example, that hand movements directed at extra-bodily targets have constant kinematic profiles, remaining straight and showing bell-shaped velocity curves with predictable acceleration at the beginning of the movement and deceleration as the target is approached (Morasso 1981). These kinematic profiles do not seem to be correlated with joint movements. There is considerable debate about whether the frame of reference on which target position is coded is egocentric or allocentric (Jeannerod 1997), but there is relatively little dispute that the coordinates are extrinsic rather than intrinsic (but see Uno, Kawato and Suzuki 1989 who suggest that the kinematic profiles observed by Morasso are consistent with the minimisation of overall joint torque).

What we have seen, at least as the phenomenology of bodily awareness is concerned, is that propositional awareness of the body derived from somatic proprioception is not coded on either an object-centred or a body-centred frame of reference. The coordinates on which the location of body-parts is coded are intrinsic rather than extrinsic. So the obvious question to ask is: how is proprioceptive content involved in the control of action? The experienced spatiality of the body, as I have analysed it, is closely bound up with awareness of the body's possibilities for action. The body presents itself phenomenologically as segmented into body-parts separated by joints because these are the natural units for movement. But what we need to know is the details of the contribution that somatic proprioception makes to the initiation and control of action.

The first point to make is that, if the spatial content of proprioception is as I have described it, somatic proprioception clearly cannot provide information about the position of the relevant limb that can *on its own* fix the initial position of the movement vector. Somatic proprioception provides information about how limbs are distributed, but this information will not suffice to fix the starting-position of the hand in a way that will allow immediate computation of the movement vector required to reach the target. Coding the starting position of the hand in the right sort of way for the calculation of the movement vector will require integrating proprioceptively-derived information with visually-derived information. This yields a testable prediction, namely, that subjects who are prevented from seeing their hands before making a reaching movement should not be capable of making accurate movements. And this in fact is what experimenters have found (Ghez, Ghilardi and Gordon 1995).

Secondly, many researchers into motor control currently think that we need to distinguish the kinematics of motor control from the dynamics of motor control (Bizzi 1999, Bizzi and Mussa-Ivaldi 2000). Movements are planned in purely kinematic terms, as a sequence of positions in peri-personal space that the hand will successively occupy during the performance of the movement. Clearly, however, the actual execution of the movement depends upon these extrinsically specified feedforward motor commands being implemented by intrinsically specified muscle forces, joint angles, joint torque and so forth. The transition from extrinsically specified coordinates to intrinsically specified coordinates comes when the nervous system computes the dynamical implementation of the kinematically specified goal. Various proposals have been made about how this computation is achieved. The traditional assumption has been the calculation of the muscle forces and joint angles required to implement the movement is achieved by working backwards from the trajectory of the endpoint. There are obvious problems of computational tractability here, particularly since the problem does not have a unique solution, as well as difficulties in factoring in biomechanical factors due to fatigue and other variables. Accordingly it has been suggested that the translation into intrinsic coordinates does not depend upon the solution of complex inverse-dynamic and inverse-computations but instead involves translating the targeted endpoint into a series of equilibrium positions (Feldman 1974).

Whether the inverse-dynamic approach or the equilibrium approach is correct, it is precisely at this point that proprioceptively derived information about the distribution of body-parts becomes crucial. The frame of reference of the intrinsic coordinates in which joint angles and equilibrium positions are coded seems much closer to the frame of reference of proprioceptive bodily awareness as I have characterised it than it is to the Cartesian frames of reference on which movement endpoints are coded. This provides a good explanation of why proprioceptive feedback is able to play such an integral part in the smooth p erformance and correction of actions, as indeed in the development of internal models of limb dynamics. The feedforward commands directed at the hand are recursively structured in much the same way as proprioceptive feedback from me hand and intervening body-segments. Motor commands to the hand need to specify approriate angles for the shoulder, the elbow and the wrist. Proprioceptive feedback about the (B)-location of the hand will equally specify the relevant : m: angles. Comparison is straightforward.

Conclusion

Let me draw the threads of the argument together. I have suggested that somatic proprioception is a source of propositional awareness of the embodied self. We experience our own bodies in a way that informs us about events taking place in the body as well as about the moment-to-moment distribution of body-parts. Many- philosophers have remarked that our experience of our own bodies is quite Unlike our experience of non-bodily objects in the world. The account I have offered of the content of somatic proprioception goes some way to explaining why this is so. Unlike our experience of extra-bodily physical objects, the experienced spatiality of the body is non-Cartesian.

The crucial role of somatic proprioception in the initiation and control of action comes at the point of transition between kinematic plan and dynamic instruction, as well as later on in the execution of the movement. What makes it possible for somatic proprioception to perform this role is that the awareness of the body it provides is coded on a frame of reference that maps straightforwardly onto the internal model of limb dynamics that specifies the body's potentialities for movement.

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