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Beyond the "body-in-the-brain": A phenomenological view of phantom limbs

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Abstract
Through the influences of Descartes to Ramachandran, phantom limbs have been considered as illusory feelings caused by neural processes in the brain that are related to body representation. Extending this view to the whole body suggests that the subjective experience of one's body even without a physical basis would be constructed by neural processes. In fact, in discussing the mechanism of phantom limbs, Ramachandran clearly stated that the whole body is a phantom constructed by the brain for convenience. This is properly called the "body-in-the-brain" view. However, a detailed examination of phantom limbs in the present paper suggests almost the opposite view, although the brain can play an important role in the phenomena. I will first explain why the experience of moving phantom limbs cannot be reduced to motor imagery but should be regarded as a part of physical body movement. Thus, phantom limbs exist as a part of a patient's body schema. Next, I will discuss the original experience in which one's body itself is constituted. Drawing on Husserl's idea of "sensing," the discussion will clarify that the constituting process of the body involves the pre-reflective sense of self being located within the body. The phantom limb phenomenon illuminates the importance of the body's physical dimension, making it possible to locate itself within the world through sensing. This paper defends this line of thought as the "body-in-the-world" view.

Phantom limbs or the body-in-the-brain

We naturally reach out our hands to the ground when we fall over while walking. But it would seem strange if the same reaction were to occur following amputation of the hands or arms. In the case of phantom limbs, which is the subjective feeling that an amputated limb is still present, these strange bodily reactions actually happen after amputation. Ramachandran and Blakeslee (1998) recounted the story of a patient ("Tom") who had lost his left arm in a car accident:

> In the weeks afterward, even though he knew that his arm was gone, Tom could still feel its ghostly presence below the elbow. He could wiggle each "finger," "reach out" and "grab" objects that were within arm's reach. Indeed, his phantom arm seemed to be able to do anything that the real arm would have done automatically, such as warding off blows, breaking falls or patting his little brother on the back. Since Tom had been left-handed, his phantom would reach for the receiver whenever the telephone rang. (pp. 21-22)
>
> Knowing explicitly that his forearm did not exist anymore, Tom repeatedly experienced bodily

actions as if the amputated part were still present. He was even able to wiggle each finger and grab objects with intention.

Although symptoms vary among patients, most amputees experience phantom sensation. A study of 58 cases of limb amputation found 84% of patients reporting phantom sensation 8 days after surgery, with 90% still reporting it 6 months later (Jensen, Krebs, Nielsen, & Rasmussen, 1983). In another study of 73 soldiers who had traumatic amputation in combat, all patients had phantom sensations, with 67% experiencing phantom limb pain 6 months after amputation (Carlen, Wall, Nadvorna, & Steinbach, 1978). Whether by surgery or accident, phantom limbs are normally observed among most amputees. Considering this, the phenomena should not be reduced to mere subjective feelings with no physiological or neurological basis.

The primary question that arises is why we can experience amputated limbs that do not physically exist. Seeking the cause of phantom limbs in body-related neural processes in the brain has been relatively influential. The origin of this idea can be found in the philosophy of Descartes. From a mind-body dualistic viewpoint, Descartes (1644/1985) considered the phenomena of phantom limbs to be evidence that our sensations arise not in the body but in the brain, which is the only organ linked to the mind. As for phantom limb pain, Descartes claimed that ". . . this shows clearly that pain in the hand is felt by the soul not because it is present in the hand but because it is present in the brain" (p. 284). According to Descartes, other bodily sensations are also felt not in the body, but in the brain, given that mental phenomena do not extend into external space.

The modern physiological version of this idea is represented by the sensory homunculus of Penfield and Rasmussen (1950). In finding that electric stimulation on certain areas of the brain surface cause illusory tactile sensations, they presented a topographic representation of the sensory distribution of the body found in the cerebral cortex. The homunculus is usually illustrated with body parts along the surface of the postcentral gyrus of the parietal lobe. Activation of the homunculus causes subjective bodily sensations such as with phantom limbs where the physical body is lost.

Developing the idea in more detail, Ramachandran quoted above also supported the view that attempts to reduce phantom limbs to neural processes in the brain. Ramachandran and Hirstein (1998) emphasized neural plasticity through which the somatosensory cortex is reorganized following amputation. After loss of peripheral inputs from the amputated hand, the corresponding part in the somatosensory cortex is reorganized to be activated by peripheral inputs from other existing body parts such as the face and shoulder, which are located nearby in the topography of the sensory homunculus. For example, in the case of D.S., they were able to reproduce the feeling of a phantom hand by stimulating his cheek at the detailed level of a digit. Phantom limbs can be produced and reproduced through specific stimulation of the somatosensory cortex. This typical viewpoint reduces the phenomena to neural processes in the brain.

This view lends itself to regarding the body itself as ultimately constructed by neural processes, even when it lacks a physical or corporeal basis. This can most properly be called the *body-in-the-brain* view. In fact, discussing the mechanism of phantom limbs, Ramachandran himself clearly stated that "your own body is a phantom, one that your brain has temporarily constructed purely for convenience" (Ramachandran and Blakeslee, 1998, p. 58). Alongside this view, they conclude that we are able to subjectively experience our own physical body whether it extends into the surrounding space or not. Even without a physical body, we can subjectively experience our body when corresponding neural processes are activated within the brain.

However, can the body-in-the-brain view truly be supported? In this paper, I will provide a

detailed examination of phantom limbs suggesting almost the opposite view, although the brain does play an important role in the phenomena. First, the experience of moving phantom limbs reveals that phantom limbs cannot be reduced to motor imagery but rather understood to be a part of physical body movement. Related to this point, phantom limbs exist as a part of a patient's body schema. Next, I will discuss the original experience in which one's body itself is constituted. The discussion will clarify that the process in which a body is constituted as a body also involves the pre-reflective sense of self being located within the body. What constitutes a body is ambiguous. On the one hand, the body must have physical dimension like other objects but, on the other hand, the body must have a subjective experience of sensing.

Moving the phantom limb

As mentioned earlier, some patients feel phantom limb pain. Phantom pain is not as common as phantom limb sensation itself. Estimates indicate that 40-80% of amputees experience phantom limb pain (Kooijman, Dijkstra, Geertzen, Elzinga, & van der Schans, 2000), although a related literature review found various percentages of amputees who feel phantom pain (Hill, 1999). As is also observed in the case of other physical pains such as migraine, phantom pain differs among individual patients. The quality of phantom pain has many features. Phantom pain can be brief and rarely occurring or chronic and unbearable. It can have diverse characteristics such as stabbing, throbbing, burning, and cramping (Flor, Nikolajsen, & Jensen, 2006).

"Mirror therapy," a therapeutic method to alleviate phantom pain, was established by the pioneering work of Ramachandran and colleagues. In an experimental study by Ramachandran and Rogers-Ramachandran (1996), a mirror was placed vertically on a table so that the reflection of the patient's intact hand was superimposed on the subjectively felt position of the phantom limb (see Figure 1). As a result, 6 of 10 patients perceived movement of the phantom hand through visual feedback of the mirrored reflection, and 4 of 5 patients with involuntary painful spasms of a clenched phantom hand could open the phantom hand by looking at the mirrored reflection of an opening hand, thus relieving the painful spasms. As that study suggests, many clinical cases of phantom pain tend to be observed in stiff and unmovable phantom limbs. A more recent study confirmed a significant

Figure 1. Mirror therapy. Retrieved from the website of Center for Brain and Cognition, UC San Diego (http://cbc.ucsd.edu/~lseckel/haiti.html).

negative correlation between phantom pain and voluntary movement of the phantom limb (Osumi et al., 2015). In mirror therapy, the ability to move a phantom limb voluntarily using the mirrored reflection of an intact hand is an important, almost crucial factor in alleviating phantom pain (Chan et al., 2007).

What is surprising in this context is that patients can learn "how to move" phantom limbs through virtual visual feedback using a mirror. Patients such as Tom mentioned above can move a phantom limb voluntarily or experience its involuntary movements in reaction to a given situation. Even when patients cannot move their phantom limbs at the outset, they are still open to learning the motor skill of moving them. This issue was recently investigated in an experiment that utilized intermanual transfer. Garbarini and colleagues (2018) trained amputees to move their phantom hands under an active condition (really moving their phantom hands) and imaginary condition (mentally moving their phantom hands). As a result, they found that learning to move the phantom hand under the active condition led to faster performance of the intact hand through intermanual transfer. Thus, patients can newly learn how to move their phantom limbs.

The difference between "really" moving a phantom limb and moving it "mentally" must be explained. For those who have not experienced phantom limbs, the experience of moving a phantom limb would be similar to imagining movement of a real limb as practiced in sports mental training. However, a neurocognitive study comparing these two conditions found them to be substantially different (Raffin, Mattout, Reilly, & Giraux, 2012). During executed movements of phantom limbs ("real movement") , more activity was observed in the primary somatosensory cortex, the primary motor cortex, and the anterior lobe of the cerebellum, whereas during imagined movements of phantom limbs ("mental movement") , more activity was observed in the parietal and occipital lobes and the posterior lobe of the cerebellum. Curiously, as suggested by the authors, this contrast in brain activity means that phantom limbs movements are *very similar to executed movements of intact limbs* and are *different from imagined movements of phantom limbs*.

This is not the entire story. Raffin, Giraux, and Reilly (2012) reported that executed movements of phantom limbs are associated with *stump muscle contractions*, whereas imagined movements of them are not. In other words, the difference between real movement and mental movement of phantom limbs was not only reflected in brain activity but also based on the *peripheral reaction of the physical body*. The patients themselves experienced moving the phantom limb in continuity with other existing parts of the body rather than moving the phantom limb selectively. It is like having to slightly contract our forearm muscles to clench our hand. The hand movement is not completed by the hand alone but involves muscle contractions of the connected parts.

Let us recall the conceptual difference between body image and body schema. They are different yet closely related systems that interact with each other in a concrete action. As Gallagher (2005) nicely summarized, "a body image consists of a system of perceptions, attitudes, and beliefs pertaining to one's own body. In contrast, a body schema is a system of sensory-motor capacities that function without awareness or the necessity of perceptual monitoring" (p. 24). A crucial difference in this definition lies in their objective functions. As body image is composed of perceptions, attitudes, and beliefs *pertaining to* one's own body, the body appears as an object for our cognitive processes. In contrast, the body does not appear as an explicit object for our cognition when the body schema mainly functions. As seen in most ordinary movements such as walking, the body itself as a subject spontaneously organizes the related body parts into a unified movement without explicit awareness (Tanaka, 2013).

Drawing on this conceptual distinction, the experience of moving a phantom limb is based not on body image but on *body schema*. It is not a type of movement in which a patient must conceptualize the body in motion before carrying it out the way a novice would learn how to juggle. Recall that Tom's body reacted to a given situation almost automatically. As quoted earlier, "[Tom's] phantom arm seemed to be able to do anything that the real arm would have done automatically." Tom's entire body, including the amputated part, was involved in the movement. Phantom limb moved as a part of habitual bodily actions deeply rooted in the body schema, which enables the patient to move without the need for conscious monitoring.

More importantly, we must rid ourselves of the prevailing misunderstanding about the very idea of movement. In general, we tend to conceptualize movement as a subject-object dichotomy, with the self as moving subject and the body as moved object. However, this is not the case in our ordinary experience of movement. When I grab a cup of tea, my awareness is directed not at my moving arm but rather at the cup. I do not even try to move my arm. If I intend to drink tea, my intention is implicitly translated into the smooth movement of reaching and grabbing. Rejecting the subject-object dichotomy, Merleau-Ponty (2012) described movement as follows:

> I move my body directly, I do not find it at one objective point in space in order to lead it to another, I have no need of looking for it because it is always with me. I have no need of directing it toward the goal of the movement, in a sense it touches the goal from the very beginning and it throws itself toward it. In movement, the relations between my decision and my body are magical ones. (pp. 96-97)

I do not move my own body by locating it at a certain point in external space before moving it toward the goal. The "I" as moving subject and "body" as moved object are not two divided components; rather they are continuously interlaced within the same spatiality. As far as movement is possible, phantom limbs are also interlaced with the patient's "I" in the same spatiality. Despite lacking a physical dimension, phantom limbs remain constituted as a part of "my body" for patients.

From the viewpoint of "being-in-the-world"

On the one hand, phantom limbs cannot be reduced to neural processes in the brain, and they constitute a part of one's subjective body ("my body") as incorporated into the same spatiality of the patient's self and physical body. On the other hand, even though phantom limbs can be moved, they obviously lack physical dimension and can never be constituted as well as the rest of the body. Patients can never complete an aimed action with phantom limbs. When the telephone rings, Tom's phantom hand reaches for the receiver but cannot answer it. In terms of affordances (Gibson, 1979), patients still perceive their environment filled with the same affordances, but their attempts at concrete action must fail.

Merleau-Ponty (2012) attempted to understand phantom limbs from the viewpoint of "being-in-the-world," which he inherited from Heidegger (1962). For Heidegger, the term "in-the-world" did not merely signify spatial inclusion; therefore, Merleau-Ponty also emphasizes that the body is not contingently included in the world, but rather intertwined with the world through its capability for action. As "I" am an embodied agent, the world always appears to me as a place for action in correspondence to my capability: A lake appears to me as a place for swimming because I know how to swim, and even a cliff appears to me as a wall to climb if I can climb rocks. To the extent that I am an embodied agent with diverse capabilities for actions, the world will always appear to me in the

mode of "I can." The surrounding environment that I perceive here and now is filled with potential opportunities for action (i.e., Gibsonian affordances; Gibson [1979]) with a familiar appearance, which Merleau-Ponty (2012) called "physiognomy" along with Gestalt psychologists.

In short, *being-in-the-world* from Merleau-Ponty's perspective signifies an embodied agent's intertwinement with the world through its capability for action. And the body schema underpins the concrete aspect of being-in-the-world, in that it organizes bodily movements into a unified action toward the environment according to one's own intention (Tanaka, 2021). In this regard, the amputated part of a patient's body remains incorporated into the body schema, with the whole body, including that part, continually reacting to the environment in a habitual manner. This is what is subjectively experienced as phantom limb sensation. However, a phantom limb lacks physical dimension and so aimed action with a phantom limb can never be completed. The patient's body is invited to act habitually toward the environment, but the expectation is betrayed upon executing the action. Merleau-Ponty described this paradox as follows:

> To have a phantom limb is to remain open to all of the actions of which the arm alone is capable and to stay within the practical field that one had prior to the mutilation. The body is the vehicle of *being in the world* and, for a living being, having a body means being united with a definite milieu, merging with certain projects, and being perpetually engaged therein. In the evidentness of this complete world in which manipulable objects still figure, in the impulse of movement that goes toward it and where the project of writing or of playing the piano still figures, the patient finds the certainty of his [bodily] integrity. But at the very moment that the world hides his deficiency from him, the world cannot help but to reveal it to him. (p. 84, emphasis added)

With this perspective, the phantom limb clearly never disappears solely by intellectual recognition of the fact of amputation. The core of phantom limb sensation is implicit or unconscious rather than explicit or conscious.

In relation to this point, one theory regarded phantom limbs as psychogenetic symptoms before current neuroimaging studies became popular among researchers. This psychogenetic view emphasized the affective aspect of the amputation experience. According to Szasz (1988), who attempted to understand pain from a psychoanalytic perspective, amputation was originally a painful and distressing experience of losing one's own body part that developed into one's unconscious denial of the loss itself. Although this denial stabilized the patient's ego at the conscious level, repressed memories of the traumatic experience were charged with negative affectivity at the unconscious level. However, what was denied and repressed in the unconscious did not disappear but reappeared in the patient's consciousness as a representation of the traumatic experience, that is, the phantom limb and phantom pain. Thus, from a psychoanalytic perspective, during the treatment process the patient needs to recall the distressing memory and discharge negative affectivity related to the traumatic amputation experience.

However, I believe it would be difficult to eliminate the phantom limb itself through psychoanalytic treatment, although it might alleviate phantom pain. The treatment deals with the unconscious representation of the body, that is, a kind of *body image*. The treatment helps the patient accept the post-amputation body, which would only change the patient's emotional attitude toward her own body (affective aspect of body image) but not necessarily the patient's habitual actions based on the *body schema*. As noted earlier, understanding the phantom limb from the viewpoint of being-in-the-world requires us to regard the patient's body as intertwined with the world through her action capabilities. If so, for the patient to eliminate the phantom limb, she must establish a new manner

of interacting with the world with her new body having an amputated part. In fact, Sobchack (2010) described how her own phantom limb sensation changed in form when she started to use a prosthesis.

It should now be clear that we cannot reduce phantom limbs to neural processes in the brain or to psychodynamic processes in the unconscious. The former fails to view the embeddedness of the body in the world whereas the latter fails to regard the body as a subject of action in the world based on the body schema. My view of phantom limbs has been influenced by Merleau-Ponty, who emphasized the body schematic feature and environmental embeddedness. This can properly be called the "body-in-the-world" view. The remainder of this paper will develop this view.

Shapes of phantom limbs

Apart from movement, there is another contradictory issue between the body-in-the-brain view and the body-in-the-world view: the subjective sensation of the shape of phantom limbs. Even in cases where patients feel no movement, they often sense the illusory shape and volume of their phantom limb. From Figure 2 (borrowed from Melzack [1990]), we can easily imagine that awareness of phantom limbs involves sensing their shapes. Dotted lines in the figure indicate patients'subjective awareness of phantoms limbs and solid lines indicate the most vividly experienced parts. Although phantom limbs tend to shrink in their length and even telescope into the stumps over time after amputation, they obviously have certain forms that focus on distal parts such as hands and feet. Fraser (2002) also found that most amputees in her study indicated that their phantom limb took the general shape of the limb prior to amputation. According to the body-in-the-brain viewpoint, this is the result of illusory proprioception generated through certain neural processes in the somatosensory cortex, which are projected onto the external space where the patients'original limb used to be.

How would this be understood from the body-in-the-world view? Regarding the perception

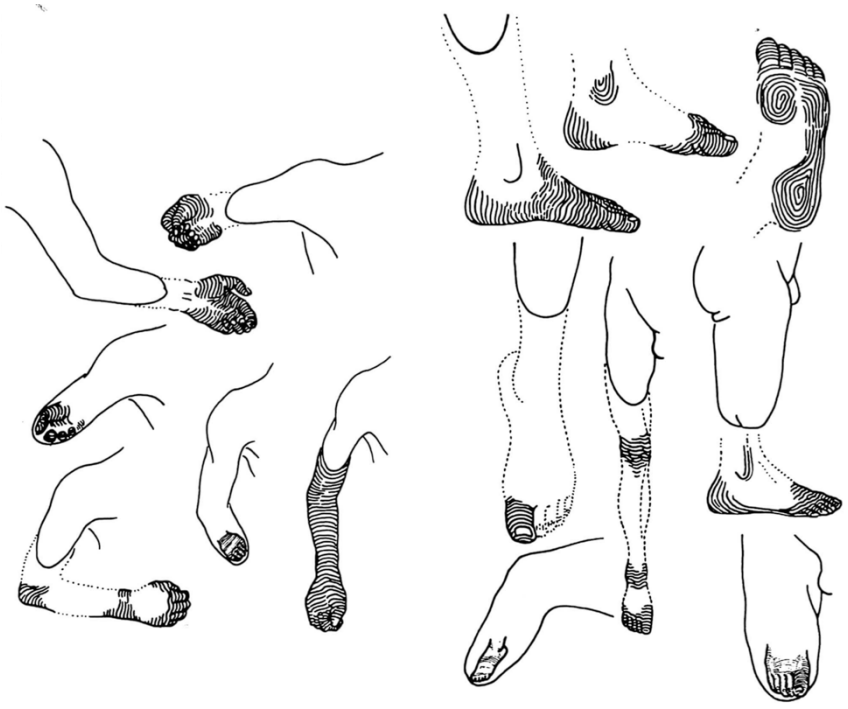

Figure 2. Drawings of phantom limbs based on patient report (Melzack, 1990).

of shape, it is very helpful to refer to Gibson's (1962) ideas on "active touch," which enables us to perceive the shape of physical objects. Using small cookie cutters of various shapes including a star, a triangle, etc., Gibson compared two patterns of object perception by touch. In the first condition, participants received only passive stimulation (cookie cutters pressed onto a hand with their eyes closed), after which they rarely perceived the cookie-cutter shapes. In the second condition, participants investigated the objects (moving their hand actively but with their eyes closed), after which they precisely perceived their shapes. Investigating objects through active touch is key to shape perception of physical objects. Tactile stimulation of the skin is not enough to elicit shape perception because such stimulation is rather flat and two-dimensional. Therefore, tactile stimulation must be combined with somatosensory stimulation derived from active movement of the body.

As for vision, one perceives an object as an invariant that appears through optical flow in accordance with one's bodily movements (Gibson, 1979). Importantly, air that surrounds one's body and transmits light serves as the very medium through which visual objects are able to appear to the perceiver. The medium and sensational flow are necessary conditions for the perceiver to visually perceive an object from Gibsonian perspective. Similarly, in the case of touch, one perceives an object as an invariant that appears through sensational flow in accordance with one's bodily movements. Here, passive tactile stimulation of the skin alone obviously is not enough to create sensational flow because there is no bodily movement or medium through which one can perceive the object. Concerning haptic perception, Gibson (1966) stated that "the unity of the perception cannot come from the skin alone. It must come from the bones and the skin together in terms of the spatial invariants that relate them" (p. 126).

Although Gibson (1966) did not explicitly account for the medium in the case of haptic perception, Murata (2019) pointed out that one's flesh serves as the medium transmitting tactile stimulation from the skin and somatosensory stimulation from the joints, bones, and muscles. One's flesh serves as a medium filled with sensational flow through which haptic objects as invariants appear to the perceiver. Especially, joints and bones always constitute a three-dimensional disposition in contrast to the rather flat surface of the skin. When both features are combined properly, one haptically perceives the shape of a three-dimensional object. Gibson (1966) wrote:

> The disposition of all the bones, at any moment in time, can be thought of as a sort of branching vector space in the larger space of the environment, specified by the set of the angles at all joints relative to the main axes of the body. And now, be it noted, cutaneous touch re-enters the picture, for the layout of environmental surfaces in contact with the members of the body and the disposition of the members of the body go together. In this way a sitting man might feel the shape of the chair as well as the shape of his body in the chair. Thus a child who grasps a ball might feel the shape of the object as well as the shape of his grasping fingers. (p. 102)

Note that Gibson described both shape perception of an external object and shape perception of one's own body as one and the same experience. When one perceives the shape of an external object, one also feels the shape of one's own body. However, the latter usually remains implicit because one's attention is directed to the object while one perceives things in the environment. Perception of one's own body constitutes the implicit "background" to which object perception appears as a "figure." It is the function of body schema that constitutes this figure-background structure in perception (Tanaka, 2021). Nevertheless, it is worth noting that shape perception of an external object and that of one's own body are two sides of the same coin.

Here is a clue to consider the shape of phantom limbs. As seen already, the amputated part of

a patient's body is still incorporated in her body schema, and body schema as a whole reacts to the environment by projecting diverse possibilities for habitual actions. If a chair is located near a patient's body, her body schema projects the possibility of implicitly sitting on it. If there is a ball, her body schema projects the possibility of implicitly grasping it. Even though the patient cannot execute the real action, micro movements, including slight changes in the disposition of bones and joints, would bring forth rich sensational flow within the flesh. And through this sensational flow, borrowing Gibson's words, the patient would kinesthetically anticipate ". . . the shape of the chair as well as the shape of his body in the chair" and ". . . the shape of the object as well as the shape of his grasping fingers." It is more than curious that patients tend to feel more vividly the distal parts of the body such as hands and feet that are utilized to touch external objects.

Thus, the shape of a phantom limb would depend on the tendency of its movement. If a patient's body tends to react to the environment in a manner established before amputation, she would clearly feel the shape of the amputated part. In contrast, if the patient establishes a new manner of acting in the environment without using the amputated part, its shape would not be clearly felt.

Constitution of the body, constitution of the self

Again, let us confirm the facts not conducive to the viewpoint that reduces phantom limbs to neural processes in the brain. First, patients can move their phantom limbs. These movements are not mere mental images but real movements grounded in the stump muscles and other existing parts of the body. Second, a phantom limb is not a body image that can be represented as a mental object, but rather it is a constituent of a significant part of a patient's body schema. The remainder of the physical body serves as a medium through which the phantom limb appears as a "limb" with three-dimensional shape. Thus, phantom limbs cannot be the evidence that supports the body-in-the-brain view, which maintains that the body itself is a production of neural processes without physical basis as claimed by Ramachandran and other researchers. In contrast, the very existence of a phantom limb, including its movement and shape sensation, depends on the remainder of the body, which implies both the physical body and the body schema. In phenomenological terms (as well as in ordinary German), the former corresponds to Körper (the physical body) and the latter to Leib (the lived body). In the following, let us consider how the body itself is constituted such that it involves both dimensions.

In asking how one's body is constituted, Husserl (1989) focused on a scene in which one perceives one's own body. When I perceive my own body, I can do it in two ways: I can look at it and I can touch it. For example, I can look at my left hand on the desk and I can touch it with my right hand. However, these two ways differ in how the perceived body (the left hand) appears to me. When I look at my left hand, it appears as an object just as other objects appear in the visual field. Differently, when I touch my left hand with my right hand, the left hand appears as a touched object but it also touches back, or more accurately, senses back the right hand. On the very spot on the left hand where it is touched it senses the warmth of the touching right hand. This experience of sensing back never occurs to me when I touch other material things. Thus, the body appears to me both as a *perceived object* and as a *localized sensing subject*. Husserl (1989) claimed:

> Hence the Body is originally constituted in a double way: first, it is a physical thing, *matter*; it has its extension, in which are included its real properties, its color, smoothness, hardness, warmth, and whatever other material qualities of that kind there are. Secondly, I find on it, and I *sense*

> "on" it and "in" it: warmth on the back of the hand, coldness in the feet, sensations of touch in the fingertips. I sense, extended over larger Bodily areas, the pressure and pull of my clothes. Moving my fingers, I have motion sensations, whereby a sensation in an ever changing way extends itself over and traverses the surface of the fingers, but within this sensation-complex there is at the same time a content having its localization in the interior of the digital space. (p. 153, emphasis in original)

The body cannot be reduced to a mere physical thing because I "sense" through it. The experience of sensing can be dispersed throughout the whole body, such as when I am running in a park, or it can be focused on a particular part of the body, such as when I am tasting wine. Be it dispersed or focused, it is important to note that the sensing experience is always localized in a particular space that is subjectively experienced as "here," where I touch the object and also sense the touching subject *in a double way*. This is how the body is constituted. Different from other physical things, the body senses itself from within, although the body itself is one of the physical things in the world.

Husserl (1989) emphasized the localized feature of sensing. On the one hand, the body extends into space and has material qualities like other physical things. Especially when I look at my own body, I can locate it "there" as I find any other physical object "there" in the external space. On the other hand, I always find my own body "here" as a "bearer of localized sensations" (p. 152). The experience of sensing is doubled as in the case of self-touching: Sensing occurs at a spot where I touch an object that is located in the external space ("there") , and at the same time, occurs "on" or "in" a particular part of the body, which brings forth the internal space where the sensing "I" am located ("here") .

Therefore, sensing is a fundamental experience (a) through which the body is constituted as differentiated from other physical things and at the same time (b) through which the sensing "I" appears in the world as localized at a subjectively experienced "here." Sensing occurs in a localized manner. It does not occur anywhere in the world but in a particular spot where the world itself diverges into the internal and the external or the mental and the physical, that is, the sensing self and the sensed world. The "here" is a spot crucially different from any other spots in the world where sensing does not occur. Sensing is a *self-referential* experience in that the sensing subject constitutes itself "as" the body and "in" the body, and is differentiated from external space that is located "out" of the body. When the body is constituted, the "I" that is sensing within it is also constituted. In addition to the above-quoted passages, Husserl (1989) also stated:

> The touch-sensing is not a *state* of the material thing, hand, but is precisely the *hand itself*, which for us is more than a material thing, and the way in which it is mine entails that I, the "subject of the Body," can say that what belongs to the material thing is its, not mine. (p. 157, emphasis in original)

The body is differentiated from other physical things for sensing, the experience of which entails the "I" that is touching the object through "my" hands.

We must again ask, what are phantom limbs? In Tom's case, he "could wiggle each'finger,''reach out,'and'grab'objects within arm's reach." Although Tom obviously could not move objects, he could still experience what we would describe as "sensing" through his phantom arm. When the phantom arm grabs an object, it never really touches it at the physical level, but rather the touching experience occurs "here," where both the touching body and the touching "I" are constituted in a localized manner. We must now clarify the factor that distinguishes real limbs from phantom limbs.

To that end, we will more thoroughly consider the experience of self-touching. When I touch

my left hand with my right hand, I can feel the softness of the flesh and the smoothness of the skin through my touching right hand, and I can also feel the warmth of the right hand on the surface of the left hand. However, if my left hand were a phantom, it would be impossible for me to feel softness or smoothness of it because a phantom hand simply lacks the physical dimension necessary for it to appear as a material object in the world. Even though my phantom left hand can "grab" objects as a part of my body schema, it can never be touched as a part of my physical body. Thus, one can say that phantom limbs are constituted only as Leib (lived body) but not as Körper (physical body). The real body is always constituted in dual dimensions. As Fuchs (2018) emphasized, we normally experience the lived body and the physical body as *coextensive*, which is not completed in phantom limbs.

Merleau-Ponty (2012) also considered the experience of self-touching in terms of double sensations, where there occurs ". . . an ambiguous organization where the two hands can alternate between the functions of'touching'and'touched'" (p. 95). When the touching hand is being touched back or when my touched left hand senses the warmth of my right hand, "the body catches itself from the outside in the process of exercising a knowledge function; it attempts to touch itself touching, it begins'a sort of reflection,'and this would be enough to distinguish it from objects" (p. 95). As Merleau-Ponty pointed out, the experience of self-touching is a bodily reflection through which the touching "I" is reflected as "me" (Tanaka, 2018). Here lies the difference between object-touching and self-touching. When one touches an object, the experience of sensing occurs and the world diverges into the sensing "I" and the sensed world. However, at this level that phantom limbs can easily access, the sensing subject "I" still lacks the experience of self-touching, that is, self-reflection. Although phantom limbs are constituted as a lived body, they generate the "I" that is no more than the pre-reflective self, being confined within the experience of sensing. The reflective-self that is constituted between "I" and "me" requires the duality of the lived body and the physical body. In short, phantom limbs are the Leib without Körper and are part of the sensing "I" that cannot generate bodily self-reflection.

Conclusion

According to the body-in-the-brain view, the subjective experience of one's own body is ultimately reduced to neural processes related to body representation in the brain. Even without a physical body, one can experience one's body when corresponding neural processes arise within the brain. It is now clear that the body-in-the-brain view should be replaced by the body-in-the-world view. For the body to be constituted as a body, it needs to exist as a physical being in the world. This physical being then needs to generate sensing, which constitutes it as a body being localized "here" in a particular spot in the world. Through the sensing experience, the world diverges into an "I" as the sensing subject and the physical world as the sensed object. From our viewpoint, both constitution of the body and constitution of the self originates from the same sensing experience, which is a self-localizing and self-referential event in the world. Here we might find the proper function of the brain. As the central nervous system, the brain seems to play a significant role in generating the sensing experience, which has a self-referential character. Being located within and as a part of the body, the brain reflects information derived from the peripheral parts of the body. This mirroring relation between the brain and the body would be the underpinning structure of the self-referential character of sensing. The brain does not hold body representation without the physical body but rather resonates with it being contained within it.

The self-referential character of sensing is further elaborated through self-touching. Here again we encounter the important role of the body's physical dimension (Körper). As we have already seen, double sensation does not occur on the phantom limb because it lacks the physical dimension. As self-touching is simply impossible for the body-in-the-brain, it never can generate reflective self-consciousness. The experience of self-reflection occurs when the sensing body further reflects on itself through self-touching; that is, the "I" reflects "me." This only happens for a body accompanied by dual aspects of Leib and Körper. When Leib touches a part of itself as Körper, Körper reverses into Leib and senses back the touching hand. This reversibility is built into the body and underpins the experience of self-reflection. If the whole body were a phantom or a body-in-the-brain from the very start, that body would never achieve self-touching or self-reflection. Contrary to Cartesian intuition, the reflective self-consciousness of "I think" is not an experience that can occur without the body, but is an experience abstracted from the body accompanied with reversibility between Leib and Körper.

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