©1995 The Institute of Mind and Behavior, Inc.
The Journal of Mind and Behavior
Autumn 1995, Volume 16, Number 4
Pages 369–390
ISSN 0271–0137

Body Image and Body Schema in a Deafferented Subject

Shaun Gallagher
Canisius College
and
Jonathan Cole
University of Southampton and *Poole Hospital, Dorset*

This paper employs a conceptual distinction between body image and body schema to clarify the experience of a patient who has lost the sense of touch and proprioception from the neck down. As a result of a large fiber peripheral neuropathy, the patient has lost the major functional aspects of his body schema, and thereby the possibility of normally unattended movement. To maintain control of posture and movement, he is forced to compensate for that loss by depending on the perceptual system of a body image that is modified in important respects. Both the conceptual distinction and the real relations that exist between body image and body schema are clarified by an examination of the specific limitations placed on motor control in this patient.

In a majority of situations the normal adult maintains posture or moves without consciously monitoring motor activity. Posture and movement are usually close to automatic; they tend to take care of themselves, outside of attentive regard. One's body, in such cases, effaces itself as one is geared into a particular intentional goal. This effacement is possible because of the nor-

Both authors would like to thank the subject, IW, for his continued interest and help, and Anthony Marcel (Medical Research Council, Applied Psychology Unit, Cambridge, England) for his helpful comments on an earlier draft. For preparation of this paper Shaun Gallagher received support from the National Endowment for the Humanities Summer Stipend (#FT–40362–94), and as Visiting Scientist at the Medical Research Council's Applied Psychology Unit, Cambridge, England. Jonathan Cole received support from the Wessex Medical Trust and Salisbury District Hospital. Requests for reprints should be sent to Shaun Gallagher, Ph.D., Philosophy Department, Canisius College, 2001 Main Street, Buffalo, New York 14208–1098.

mal functioning of a body schema. Body schema can be defined as a system of preconscious, subpersonal processes that play a dynamic role in governing posture and movement (Head, 1920). There is an important and often overlooked conceptual difference between the subpersonal body schema and what is usually called *body image*. The latter is most often defined as a conscious idea or mental representation that one has of one's own body (see for example, Adame, Radell, Johnson, and Cole, 1991; Gardner and Moncrieff, 1988; Schilder, 1935). Despite the conceptual difference many researchers use the terms interchangeably, leading to both a terminological and conceptual confusion.[1]

Gallagher (1986) has argued that a clear conceptual distinction between body image and body schema would be helpful in working out their functional differences. But the conceptual distinction should not imply that on the behavioral level the image and schema are unconnected or that they do not sometimes affect one another. To develop the distinction further and to clarify the functional interrelations of body image and schema, this paper examines the unusual case of a subject with a severely impaired body schema. IW suffers from the effects of a large fiber peripheral neuropathy that involves the loss of proprioception and the sense of touch from the neck down (Cole, 1995). Despite the dramatic effects of the disabling neuropathy IW regained a controlled posture and locomotion by consciously monitoring his position and movement. We suggest that, in this case, control over posture and movement were achieved by a partial and imperfect functional substitution of body image for body schema.

Body Schema and Body Image: A Conceptual Distinction

In a recent review, Parsons (1990) defines the concept of *body image* in a complex and ambiguous way. On the one hand, he considers the body image to be nonconscious: a set of "processes underlying the mental simulation of one's action and . . . not directly accessible to consciousness" (p. 46). In this sense it operates as a subpersonal representation that depends on information provided by "proprioceptive, kinesthetic, muscular, articular, postural, tactile, cutaneous, vestibular, equilibrium, visual, and auditory senses, as well as [information] from our sense of physical effort and from contact with objects

[1]Thus, for example, Fisher (1972) provides the following influential definition: "Body image can be considered synonymous with such terms as 'body concept' and 'body scheme.' Broadly speaking, the term pertains to how the individual perceives his own body. It does not imply that the individual's concept of his body is represented by a conscious image . . . . Body image . . . represents the manner in which a person has learned to organize and integrate his body experiences" (p. 113). The terminological and conceptual confusion is noted by, e.g., Garner and Garfinkel, 1981; Shontz, 1974.

and among our body parts" (p. 46). On the other hand, Parsons, citing Lackner (1988), indicates that some of this information contributes to a conscious, perceptual representation of the body, the "mental simulation" itself, in which "the apparent position of some parts affects the represented shape of others" (p. 46). He also cites Head (1920) and uses the term *body schema* interchangeably with *body image*.

This recent definition expresses an ambiguity that has characterized studies of body perception since Schilder (1935) used the terms *body image* and *body schema* interchangeably to signify the image or conscious representation of one's own body. Poeck and Orgass (1971) and Gallagher (1986) summarize a long tradition of ambiguous terminological usage and conceptual misusage in clinical studies of body perception and movement. In light of the fact that the terms *schema* and *image* have frequently been used interchangeably to mean processes that range from reflective cognition, to physiological functions, to unconscious representation, a clear conceptual distinction may be helpful for understanding both the production and the perception of movement. Among the various issues involved in the problem of defining the distinction between schema and image the following one is most relevant to our considerations here.

The *body image* consists of a complex set of intentional states — perceptions, mental representations, beliefs, and attitudes — in which the intentional object of such states is one's own body. Thus the body image involves a reflective intentionality. Three modalities of this reflective intentionality are often distinguished in studies involving body image (e.g., Cash and Brown, 1987; Gardner and Moncrieff, 1988; Powers et al., 1987).

(a) the subject's *perceptual* experience of his/her own body;
(b) the subject's *conceptual* understanding (including mythical and/or scientific knowledge) of the body in general; and
(c) the subject's *emotional* attitude toward his/her own body.

The latter two aspects, (b) and (c), do not always involve conscious awareness, but are maintained as a set of beliefs or attitudes and in that sense form part of an intentional system.

In contrast to the reflective intentionality of the body image, a *body schema* involves a system of motor capacities, abilities, and habits that enable movement and the maintenance of posture. The body schema is not a perception, a belief, or an attitude. Rather, it is a system of motor and postural functions that operate below the level of self-referential intentionality, although such functions can enter into and support intentional activity. The preconscious, subpersonal processes carried out by the body-schema system are tacitly keyed into the environment and play a dynamic role in governing posture and movement. Although the body-schema system can have specific effects on cognitive experience (Gallagher, 1995), it does not have the status of a conscious representation or belief.

In most instances, movement and maintenance of posture are accomplished automatically by the body, and for this reason the normal adult neither needs nor has a constant body awareness. Indeed, in most activities that are oriented toward an intentional goal the body tends to efface itself with respect to conscious awareness. This functional effacement of the body is possible because in normal circumstances a body schema continues to perform its motor and postural functions without need of conscious control. It continues to operate, and in many cases operates best, when the intentional object of perception is something other than one's own body. Crook makes this point clear: "We all know that in normal conscious states our awareness of bodily sensation is limited — pushed aside by the fact that our attention is locked upon some social or situational issue. It is almost as if (as in the learning of a task) the functions of the body are on automatic pilot and do not usually have to be attended to consciously" (1987, pp. 390–391).[2]

Although the control and coordination of movements are normally accomplished by a body schema without the help of conscious attention, and in some cases even without conscious awareness of what our body is doing, there are instances in which the perception of one's own movements can be complexly interrelated to their accomplishment. Conscious perception of my own body can be used to monitor and control my posture and movements. The visual, tactile, and proprioceptive awareness that I have of my body may help me to learn a new dance step, improve my tennis game, or imitate the movements of others. Ordinarily, however, in walking I do not have to think about putting one foot in front of another; I do not have to think through the action of reaching for something. I may be marginally aware that I am moving in certain ways, but it is not usually the center of my attention. And marginal awareness may not capture the whole movement. If I am marginally aware that I am reaching for something, I may not be aware at all of the fact that for balance my left leg has stretched in a certain way, or that my toes have curled against the floor. Posture and the majority of bodily movements usually operate without the help of a body image.

To the extent that one does become aware of one's own body in terms of becoming conscious of limb position, movement, or posture, then such an awareness helps to constitute the perceptual aspect of the body image. When

---

[2]It has also been noted that "for good adaptation and responsivity to the environment the conscious perceptive field is mostly occupied by external rather than internal stimuli to which the subject tends to respond . . . . When the subject focuses on his body, different components or images of body parts, of which the subject himself usually is unconscious, can emerge" (Ruggieri, Milizia, Sabatini, and Tosi, 1983, p. 800).

the body does appear in consciousness, it often appears as clearly differentiated from its environment. Body image boundaries tend to be relatively clearly defined (see Fisher, 1964; Fisher and Cleveland, 1958). The body schema, in contrast, can be functionally integrated with its environment, even to the extent that it frequently incorporates certain objects into its operations — the hammer in the carpenter's hand, the feather in the woman's hat, and so forth. Under these circumstances one's perception of body boundary may end at one's finger tips even when a particular schema projects itself to include the hammer that one is using. This distinction is not absolute, however, and may involve a temporal component. More permanent attachments to the body — such as prosthetic devices — can become incorporated into both the image and the schema of the body affecting our bearing and approach to the world in both conscious projection and movement. Similarly some prostheses and even clothes greatly affect the way in which we view ourselves and our personal image (Saadah and Melzack, 1994).

It is also important to note that social and cultural factors affect perceptual, conceptual, and emotional aspects of body image. For example, I may be emotionally dissatisfied with the way my body looks because it does not match up to the cultural ideal of beauty or strength. Or I may be emotionally dissatisfied because of an altered and abnormal sense of body image, for example, in anorexia.

Two other issues are worth mentioning here. First, the body image, as a reflective intentional system, ordinarily represents the body as *my own* body, as a personal body that belongs to me. It contributes to a sense of an overall personal self. In some pathological cases (e.g., body neglect, anosognosia) a subject is sometimes alienated from a specific part or side of the body, and that part or side is experienced as "unowned" or owned by someone else. Clearly this can be described as a distortion of body image.

In contrast to both normal and abnormal experiences of body image, the body schema consists of a system of prepersonal, anonymous processes. Even in cases of intentional movement, most bodily adjustments that subtend balance and posture are not subject to my personal decision. Rather, various neural motor programs command muscle groups to make automatic schematic adjustments that remain below the threshold of my awareness and outside of my personal control. In some cases of body neglect it is possible for the body schema to function normally in spite of extreme problems with body image. Thus, in a subject who suffers from body neglect, the neglected side of the body may still function in processes like walking, dressing, and eating (Denny–Brown, Meyer, and Horenstein, 1952; Melzack, 1989).

Second, body image involves a partial, abstract, and articulated perception of the body insofar as thought, attention, and emotional evaluation attend to only one part or area or aspect of the body at a time. It is also possible that as a set of beliefs or attitudes about the body, the body image can involve inconsistency or contradictions. The body schema, on the other hand, functions in a more integrated and holistic way. A slight change in posture, for example, involves a global adjustment across a large number of muscle systems. Proprioceptive information, originating in different parts of the body, does not function in an isolated or disintegrated manner but adds together to modulate postural control (Roll and Roll, 1988).

The conceptual distinctions that we have outlined are based more on phenomenology than on a study of empirical function, and they do not tell us in precise terms what the body schema is or how it functions. Furthermore, sensory and motor aspects of experience are difficult to separate because they alter each other in a reciprocal fashion. A number of questions can be raised in this context: To what extent may the body schema be separated into sensory and motor components and what might the interrelationship between these two aspects be? To what extent does the body schema play a role in the production of the body image? How do proprioceptive information and the performance of movement structure body perception? Also, what role does the perception of movement (the body image) play in the performance of movement?[3] In other words, although we have argued for a conceptual distinction between body image and body schema, it also seems reasonable to believe that body image and body schema are interrelated on the level of motor behavior and proprioceptive processes. To clarify these issues we examine an extremely unusual case of a subject, IW, who has lost proprioception and the sense of touch from the neck down. As a result his movement is accomplished under the control of a highly developed body image, and without the full contribution of a body schema.

A Case of Impaired Body Schema

IW suffers from an acute sensory neuropathy in which large fibers below the neck have been destroyed by illness.[4] As a result IW has no proprioceptive function and no sense of touch below the neck. He is still capable of movement and he experiences hot, cold, pain, and muscle fatigue, but he has no proprioceptive sense of posture or limb location. Prior to the neuropathy he had normal posture and was capable of normal movement. At the onset of

---

[3]For a discussion of developmental questions in this context, see Gallagher and Meltzoff (in press).

[4]This happened in 1971 when IW was 19. The onset of the neuropathy was acute following an illness documented at the time as infectious mononucleosis. Neurophysiological tests confirm the loss of large myelinated fibres below the neck (Cole and Katifi, 1991). Also see the sensory neuronopathy described by Sternman, Schaumberg, and Asbury, 1980.

the neuropathy IW's initial experience was of complete loss of control of posture and movement. He could not sit up or move his limbs in any controllable way. For the first three months, even with a visual perception of the location of his limbs, he could not control his movement. In the course of the following two years, while in a rehabilitation hospital, he gained sufficient motor control to feed himself, write, and walk. He went on to master everyday motor tasks of personal care, housekeeping, and those movements required to work in an office setting.

To maintain his posture and to control his movement IW must not only keep parts of his body in his visual field, but also conceptualize postures and movements. Without proprioceptive and tactile information he neither knows where his limbs are nor controls his posture unless he looks at and thinks about his body. Maintaining posture is, for him, an activity rather than an automatic process. His movement requires constant visual and mental concentration. In darkness he is unable to control movement; when he walks he cannot daydream, but must concentrate constantly on his movement. When he writes he has to concentrate on holding the pen and on his body posture. IW learned through trial and error the amount of force needed to pick up and hold an egg without breaking it. If his attention is directed toward a different task while holding an egg, his hand crushes the egg.

In terms of the distinction between body image and schema, IW has lost the major functional aspects of his body schema, and thereby the possibility of normally unattended movement. He is forced to compensate for that loss by depending on his body image (itself modified in important aspects) in a way that normal subjects do not.

To what extent does IW have a body schema? At the earliest stage of his illness IW had no control over his movements and was unable to put intention into action. There was, one might say, a disconnection of will from the specifics of movement. If IW decided to move his arm in an upward direction, and then tried to carry out the intended motion, the arm and other parts of his body would move in relatively unpredictable ways. Without support, IW was unable to maintain anything other than a prone posture. He had no proprioceptive awareness of the position of his limbs, so he could not locate them unless he saw them. But even with vision, in this earliest stage, he had no control over his movement. Because of the absence of proprioceptive and tactile feedback his entire body-schema system failed.

That proprioception is a major source of information for the maintenance of posture and the governance of movement — that is, for the normal functioning of the body schema — is clear from IW's experience. But proprioception is not the only source. IW, as a result of extreme effort and hard work, recovered control over his movement and regained a close-to-normal life. He did not do this by recovering proprioceptive sense, but by rebuilding a partial body schema and by using body image to help control movement. This case, then, promises to throw light on the distinction between body image and schema, and to resolve a number of issues concerning relations between the perception and the performance of movement.

Movement With and Without Proprioception

The body schema consists of certain functions that operate across various parts of a complex system responsible for maintaining posture and governing movement. This system might best be conceived as consisting of three sets of functions. The first set involves the input and processing of new information about posture and movement that is constantly provided by a number of sources, including proprioception. A second set involves motor habits, learned movement patterns ("motor schemas" or programs). The final set of functions consists of certain intermodal abilities that allow for communication between proprioceptive information and perceptual awareness, and an integration of sensory information and movement. In all three of its functional aspects, the body-schema system is interrelated with perceptual aspects of the body image.

Proprioception and Other Inputs

The body works to maintain posture or govern movement on the basis of information received from numerous sources. Besides proprioceptive information from kinetic, muscular, articular, and cutaneous sources, contributions also originate in vestibular and equilibrial functions. Parsons (1990) mentions visual sense as a source of information vital to posture and movement. Visual sense, in this regard, can be distinguished into (a) exteroceptive sense, that is, direct visual observation of the movements of limbs (see e.g., Crook, 1987) and (b) "visual proprioception" (Gibson, 1979; Jouen, 1988; Neisser, 1976). Exteroceptive sense (e.g., the visual perception of one's own body) helps to constitute the perceptual aspect of the body image, and in some instances contributes to a conscious control of posture and movement (Gurfinkel and Levick, 1991). Visual proprioception is more directly related to the body schema and involves the subpersonal processing of visual information about environmental motion in the visual field. Outside of conscious awareness, adjustments in posture are made in order to compensate for changes in the "optical flow" or movement in the visual environment (Assaiante, Amblard, and Carblanc, 1988; Brandt, 1988; Lee and Lishman, 1975). Extraocular muscles also provide proprioceptive information that contributes to head stabilization and whole-body posture (Roll and Roll, 1988; Roll, Roll, and Velay, 1991).

Proprioception, in the ordinary sense of being mechanical or non-visual, is obviously a major source of information concerning present bodily position and posture. Proprioception, however, serves a twofold function, and for our purposes it is important to maintain a clear conceptual distinction between proprioceptive *information*, which informs the body schema and the automatic performance of movement, and proprioceptive *awareness*, which is a conscious perception of movement and position.

Proprioceptive information consists of subpersonal, physiological information — the result of physical stimuli at certain proprioceptors. As such, proprioceptive information updates the body with respect to its posture and movement and thus plays an essential role in the body-schema system. It contributes to the automatic control of posture and movement even when my consciousness is totally taken up with action or cognition that does not involve the explicit self-referential intentionality of a body percept. Proprioceptive information in this purely physiological aspect is neither an attentive perceptual activity nor an activity that we are usually aware of. Proprioceptive information, however, can serve as the physiological basis of a body-awareness. The same proprioceptors, and in some cases the same neural structures, supply the information necessary for both the automatic governing of movement and the perceptual sensation of one's own movements (Phillips, 1986).

Thus, the term *proprioception* is often equated with joint and movement sense and defined as a form of awareness that directly provides a knowledge, representation, or image of our body (e.g., O'Shaughnessy, 1995). Because of proprioceptive awareness, for example, I can tell you where my legs are even with my eyes closed. Proprioceptive awareness is a felt experience of bodily position that helps to constitute the perceptual aspect of the body image. Although, in the normal adult, in some circumstances, proprioceptive experience may be used to monitor and assist motor activity, the majority of normal adult movements do not require anything like the explicit proprioceptive awareness involved in a body percept. Rather, posture and movement are normally governed by the more automatic processes of the body schema (Gurfinkel and Levick, 1991).

In IW there is no proprioception from the neck down, and this affects both his body image and body schema, but in different ways. Normally, information from proprioceptive and other sources constantly updates the body-schema system regarding posture and movement. Of these various sources, IW still has input from vestibular and equilibrial sources, and visual proprioception. He has a grossly impoverished sense of physical effort, but it is of no use in movement control (Cole and Sedgwick, 1992). He has lost tactile and proprioceptive information, so there is no kinesthetic, cutaneous, muscular or articular input. In effect, following the onset of the neuropathy, the major contributions of body schematic information were disrupted.

IW depends heavily on visual perception of limb movement along with visual proprioception in order to control his movement. To maintain balanced posture, for example, he has learned to designate a stationary object in the environment as a reference point which he keeps in his visual field. Deprived of vision, in a darkened room, IW will not be able to maintain posture, for then he will have lost both visual inspection of his body and visual fixation on an external point. This indicates that he makes up for his loss of proprioception with a high reliance on visual perception and visual proprioception to supply a running account of limb position. Since his muscles still work and he has a "crude" sense of effort in this connection, he is able to tense his muscles and freeze in position.[5] He can do this in an articulated manner, so, for example, he is able to maintain posture in legs and trunk while working with his hands.

All of this — visual perception of limb position, visual proprioception, freezing of position, and movement of limbs — takes an effort of concentration. Whereas in normal subjects the control of posture and movement takes place without conscious attention and without thinking about it, in IW, conscious attention — a conscious processing of information about body and environment — is what informs, updates, and coordinates his postural and motor processes.

Motor Habits

Motor habits, a repertoire of motor programs or "motor schemas," are flexible and corrigible patterns of movements. Some are entirely learned; others, which may be innate, are elaborated through experience and practice. Examples of motor habits include swallowing, walking, and writing. We normally learn to ride a bicycle or to swim, for instance, by attending to the task; but subsequently we ride or swim without any thought of motor action. Such programs may not persist indefinitely and in order to maintain them they need to be refreshed by use and resultant feedback. IW had built up a set of motor schemas over the course of 19 years prior to his illness. Although it is likely that these were not destroyed by the loss of proprioception and touch, they were no longer accessible when he lost proprioceptive feedback.

There are at least two ways to explain the effects of IW's lack of proprioceptive information on motor habits. The first involves the problem of updating and access to programs that continue to exist. When, for example, one buttons one's shirt, one accesses a motor habit that carries through the action without the need of attention to how exactly one moves one's fingers.

[5]The sense of effort is likely to be based on A-delta fibers, and this is very different from control subjects (see Cole and Sedgwick, 1992; Cole et al., 1995).

Normally this is possible because proprioceptive information updates the motor process with regard to finger location and movement. If the process is not kept updated in this manner, if proprioception fails to register the present motor state, or fails to provide the proper cues, then either the motor program cannot be accessed, even if it remains theoretically intact, or it must be accessed in an alternative way.[6] The loss of proprioceptive information, which would, in normal circumstances, keep the system updated with regard to present posture and limb position, puts IW in this type of situation — his motor system doesn't know where it is in the movement process.

A second possible explanation involves the retention or lack of retention of motor schemas. Like non-motor habits, when motor schemas are not used, they fade and cease to exist (Head, 1920). Because of the lack of proprioceptive updating, IW has been unable to put most of his motor patterns to use, and it remains unclear to what extent such patterns continue to exist, or to what extent IW can establish new motor schemas.

Observation of IW's movements, and his own phenomenological report indicate that very little of his motor activity is governed by automatic motor schemas. Although it is probable that he was able to recover as well as he has because he had already learned normal patterns of movement prior to his illness, this does not mean that the movements are the same as they were before. The differences between IW's movement and normal movement are large enough to suggest that his movements are reinvented, not reaccessed. Still, not all aspects of his movements in walking are under his volitional control the whole time. His recoveries in writing and walking, for instance, have probably depended on his ability to delegate some aspects of the motor act to a rudimentary, close to automatic, schematic level. On the first explanation, this may indicate some minimal access to intact motor schemas (Bernett, Cole, McLellan, and Sedgwick, 1989). It would be consistent with the second explanation to say, not that his movements are completely relearned motor skills or motor programs, but that the conscious control of movement becomes less exacting with practice. For example, when he relearnt to walk it required all his concentration. Now he estimates that walking over a flat, well-lit surface takes about 50–70% of his attention, though walking over an uneven surface still requires 100%. Thus, IW's suc-

[6]Volpe, LeDoux, and Gazzaniga (1979) have suggested that simple motor programs can proceed effectively without proprioceptive feedback. Their subjects, following cortical damage, suffered deafferentation limited to one arm. When provided tactile cues on relevant areas of the unaffected arm they could sometimes initiate motor programs that were accurate but not finely controlled. These subjects are quite different from IW in that they have lost sensation as a result of cortical damage, allowing for the possibility that their movements were guided by intact, but subcortical motor schemas. In the case of IW visual information is the usual cue for initiating motor programs.

cess in recovering useful movement function has depended primarily on his finite mental concentration, and, to a much lessor degree on re-accessing or re-learning motor programs which are, so far, poorly understood.

To what extent might the kind of updating provided by the visual perception of one's own limbs supply information that would allow access to or engagement of motor schemas? This remains unclear. Normally vision, understood as exteroceptive perception, is not designed to serve this function except in a very limited way. Control of volitional movement does not normally travel from the body image to the body schema except in very abstract, self-conscious movement. Outside of practical situations, for example when one is thinking philosophically about the nature of the will, one might abstractly command one's arm to raise itself. But in most everyday circumstances, volitional movement means reaching to grasp something, or pointing to something, and the focus is on the something, not on the motor act of reaching or grasping or pointing. These movements tend to follow automatically from the intention. In IW, however, focused, visual attention had to be realigned toward the actual motor accomplishment.

Intermodal Communication

Just as the loss of proprioceptive information impairs the body schema and disrupts the control of posture and movement, so the loss of proprioceptive awareness results in an impoverishment of the perceptual aspect of the body image. Although IW still had a visual perception of his body, this was not enough at first to gain control over his posture or movement. Because of the absence of proprioception, another important part of the body-schema system, a capacity for intermodal communication, failed. The normal intermodal communication between proprioception and vision had been disrupted. For example, I am able to imitate the bodily movement of another person without drawing up a theory of how to do it, because what I see is automatically translated into a proprioceptive sense of how to move.[7] The possibility of intermodal translation between vision and proprioception, an innate feature of our sensory-motor system, allows visual perception to inform and coordinate movement. In IW, the language of proprioception was missing, and he had to learn to use vision (constantly updating information on present posture and movement), as a partial substitute for proprioception, to drive motor processes directly.

IW's sense of his body as under his control had disappeared. He lost not only the kind of automatic motions that allow normal subjects to walk with-

[7]This innate cross-modal function of proprioception can be seen in studies of newborn imitation (see Gallagher and Meltzoff, in press; Meltzoff, 1990).

out seeing or thinking of their legs; he lost controlled voluntary movement. Even with vision and thought he could not at first control motility. The perceptual aspect of the body image does not normally fulfill this function without the co-operation of proprioception and the body schema. In the early stage of IW's illness his body image was not adequate to compensate for the missing proprioception.

Although it is unclear how vision might control movement without proprioceptive feedback, the realignment toward visual and cognitive control of movement appears to result in some differences from normal motor control. Such differences can be ascertained through the technique of transcranial magnetic stimulation of the brain which now makes it possible to stimulate the motor system in humans at both cortical and subcortical levels. This involves a painless procedure in which a magnetic flux, discharged through a coil placed over the scalp, produces a magnetic field within the brain. This, in turn, produces a small electrical field which discharges those neurons that are close to their threshold for activation and leads to a muscle twitch (see, for example, Rothwell et al., 1987). At low intensities of stimulation only neurons close to their discharge potential are activated. Magnetic stimulation can be used, therefore, to investigate those cells being kept close to that level. In the motor system it allows study of those neurons related to the neural basis of attention to movement. In the normal subject magnetic stimulation of a small movement area of the brain will produce a small twitch movement in an arm or leg. If a magnetic pulse is superimposed at the time the subject is in the process of making a movement, then a much larger twitch is produced. In addition, the threshold to produce the twitch falls dramatically when the person is beginning a movement of his or her own.

Cole et al. (1995) studied IW using the magnetic stimulation technique. They demonstrated that he has a more focused command of movement. IW was asked to move his thumb while an appropriately directed magnetic pulse was superimposed. His focusing of command onto movement of the thumb was far more accurately limited to the thumb than in control subjects. Whereas in control subjects thumb movement facilitated other movements when magnetic pulse was superimposed, this was not the case with IW. Clearly his need to attend to his movement alters the way in which he produces a movement.

In these types of experiments, imagined movement also lowers threshold and promotes a larger twitch. IW was asked to imagine moving his thumb while a magnetic stimulation was superimposed. Under these conditions IW is still able to reduce the threshold for producing a movement in the thumb muscle alone, in contrast to control subjects who are unable to limit the effect to the thumb muscle (Cole et al., 1995). Thus, in IW's progression from will to motor control, his voluntary control is more focused, and, compared to control subjects, there is less difference between a real movement and an imagined movement.

Image-Controlled Movement

In place of missing body schema processes, IW has substituted cognitively driven processes that function only within the framework of a body image that is consciously and continually maintained. If he is denied access to a visual awareness of his body's position in the perceptual field, or denied the ability to think about his body, then his motor control ceases to function. What is the exact nature of the body image that IW uses to control his posture and movement? To what extent is his conscious effort a matter of visual attention, or simply keeping certain body parts within the visual field? To what extent does it consist of a set of judgments — i.e., thoughtful judgments about what his body is doing?

According to IW's own phenomenological reports, when he is moving he does not think about specific muscle groups, but simply that he will move an arm or finger. Normally when he is making a coordinated movement he will think of the co-ordinated moving part, e.g., reaching out his arm, and of the necessary postural adjustments required to avoid falling over once his balance is shifted by the outstretched arm. It appears that he does not think about muscle operations themselves. This was the case even when he was relearning to move. His conscious effort in moving essentially consists of a set of judgments or internal motor commands; he then monitors the movement with vision and uses the visual feedback to maintain movement.

There is evidence that IW has automated parts of this process. There is some phasic activation and relaxation of calf muscles in relation to gait cycle which are not under visual control and which may be nonconscious (Bernett et al., 1989). IW himself reports that walking on flat surfaces takes approximately half of the concentration required when he first relearned the process. One may hypothesize that in learning to stand and then walk part of the process involved the development of such automated or semi-automated programs for it seems inconceivable that he could attend to all aspects of walking in terms of each muscle, and simultaneously coordinate balance and forward motion. One way to conceive of this is to say that he has re-established access to motor programs learned prior to his illness; but access to motor programs is minimal or unlikely for reasons indicated above. Alternatively, he may have established some set of learned motor strategies monitored at the level of the body image — a set of sequential motor steps that he can follow without an inordinate (debilitating) amount of attention.

Some evidence for the latter alternative can be found in IW's performance in mirror drawing. When asked to trace the edges of the Star of David with a finger while viewing it inverted through a mirror, normal subjects find it difficult to turn the corners because of the conflict between proprioceptive information, not affected by the mirror, and visual information which is affected. One would expect IW to have no trouble tracing the edges, because in his case there could be no proprioceptive interference with visual guidance. Another deafferented subject, GL, who suffers from a similar loss of proprioception was able to do the task effortlessly the first time.[8] IW, however, was much more like control subjects in that when he came to a point on the star there was a conflict. This conflict, however, cannot be due to proprioceptive interference, since he has no proprioception. The hypothesis is that the interference comes from learned motor strategies or internal sequential motor images that IW generates cognitively without proprioceptive feedback. This aspect of IW's recovery, the construction of image-based motor sequences, is being investigated at present.[9]

On the basis of such motor strategies IW is able to maintain simple repetitive movement for up to a minute, for example, repetitive touching of thumb and fingers. Similar to control subjects, when required to concentrate on a simple subtraction problem (serially subtracting 4's or 7's from 100) IW's performance of repetitive movement deteriorated within seconds. In contrast to control subjects, however, to alter a repetitive movement IW requires visual feedback (Cole and Sedgwick, 1992).

There is also evidence for the retention over a period of 20 years of certain coordinated "reflex" motor actions, although they are of no use to IW in controlling movement. If one takes a drink off a tray the arm of the subject carrying the tray will move upward as the drink is taken off. The upward movement does not happen, however, if it is the holder of the tray who removes the drink. This "waiter's illusion" depends on a reflex motor program, and still occurs in deafferented subjects (Forget and Lamarre, 1995). A few other coordinated actions have been found, though interestingly none is of any use to deafferented subjects. If IW falls, for example, he has to think

---

[8]Both IW and GL lost tactile sense and proprioception, IW from the collarline down, GL from about mouth level down. IW has normal position sense for the neck, but GL has no information from her neck muscles or in the lower part of her mouth and face. Both subjects have retained vestibular information, information about head position and movement in the gravitational field. IW may be more able to focus attention on motor planning and may thus be able to construct motor images, due to the fact that he has a more stable head and neck posture than GL. One result is that IW walks; GL stays in a wheelchair. See Cole and Paillard, 1995.

[9]IW's case may throw some light on the way control subjects construct motor models. For example, how do we know how to hit a golf ball first time? Feedback will not tell us. We need to launch a motor act constructed internally, based on an image. By looking at IW's capacity to do this without feedback we can begin to reflect on how we do this ourselves.

about how to put his arms out and he can only do so slowly. He does not automatically withdraw his hand from pain.

In control subjects coordination between limbs and body is apparent in simple tasks like raising an arm. As one raises an arm a variety of muscles in other parts of the body adjust themselves in order to keep the head and the rest of the body balanced. This is an automatic function controlled on the level of body schema. In contrast, when IW moves his arm when standing he has to think about his center of gravity and he must produce opposing movements to keep his balance. In raising his hand he does not know, without visual feedback, how far it has gone. So, in order to raise it safely he has to first assess how free and safe the space is in front of him, and how safe his body position is to allow an alteration in the center of gravity relative to raising the arm. If he wants accuracy in this movement, he requires visual perception of the arm.

In IW's case a partial but very successful motor control is instituted within the framework of a consciously maintained body image. Vision and learned motor strategies help to supplement a limited amount of information that normally serves the body schema — visual proprioception, vestibular and equilibrial information, and less so, a sense of physical effort. His body image is maintained through constant visual perception (attention to body parts or awareness of the body in the visual field) and through a series of judgments and motor strategies. Anything that might upset his perceptual or cognitive processes also affects his movement. A head cold renders IW unable to do anything and he takes to his bed. In this case his visual perception may be fairly unaffected, but the effort of concentration needed to focus conscious and attentive will, required at the beginning of all his movements, is more than he can deal with.

More generally, mental control of movement is limited in four ways. First, there are attentional limitations: IW cannot attend to all aspects of movement. Second, his rate of movement is slower than normal. The fact that movement and motor programs are consciously driven slows motility down. Third, the overall duration of motor activity is relatively short because of the mental effort or energy required. Finally, complex single movements (like walking across rough ground), and combined or compound movements (walking and carrying an egg) take more energy than simple movements.

Within this set of limitations, IW has found that a body image based primarily on visual perception can substitute for proprioception, though very poorly and inadequately. Visual feedback, for instance, involves delays that are too great to allow a normal motor activity. He has learned to make gross compensatory adjustments somewhat quickly after, or along with, the movement of a limb. Still IW has to simplify movements in order to focus his command upon them. His movements appear somewhat stiff and slow and could not be mistaken for normal. Some aspects of his movement may benefit from acquired strategies concerning the adjustment of certain muscles in particular movements. IW, however, insists that once a motor behavior has been performed it does not mean that it requires less concentration subsequently. His rehabilitation necessitated huge increases in his attentional abilities. The cognitive demands of this activity cannot be over-estimated, for other deafferented subjects have not managed such a functional recovery.

Conclusions

The distinction between body image and body schema provides a useful conceptual framework for describing IW's case. At the same time the case tells us something about the real functional interrelations between body image and body schema.

The standard prepersonal functioning of proprioceptive information grants a certain freedom to the normal subject that is limited in IW. A normal subject can in a large measure forget about the body in the routine of the day. The body takes care of itself, and in doing so, it enables the subject to attend, with relative ease, to other practical aspects of life. The fact that IW, who lacks proprioception, is forced to think about his bodily movements and his posture all the time shows us the degree to which in normal subjects this is not the case, that is, the degree to which the body schema functions to control posture and movement nonconsciously without the intervention of a body image. This is not to deny that the body image may serve other important movement functions. Indeed, in terms of learning and developing novel movements and making them habitual one requires a certain perceptual awareness of the body.

The various limitations involved in the conscious and deliberate control of movement on the basis of a body image reinforces the idea that the body image involves an abstract and partial perception of the body. Conscious attention can be focused on only one part or area of the body at any moment. One cannot attend to all aspects of movement, and if one is forced to control movement by means of the body image, motility is slowed. The more complex the movement, the more aspects of simultaneous bodily adjustments one must be aware of, the more difficult it is to perform. The more IW can make his movements automatic through the use of learned motor strategies, and so the less attention that is required for movement, the easier and more natural it seems. In effect, movement appears relatively more coordinated and holistic to the degree that motor decisions have been made close to automatic and less attention is required. In IW, however, this degree is still far from normal, and the slightly stiff and deliberate character of his movements makes them appear less than holistically integrated.

In some circumstances, we suggested, the proper functioning of a body schema provides a higher degree of integration between body and environment, incorporating elements that are not part of the body or necessarily reflected in the body image. In one circumstance IW approaches this kind of integration. In the experience of driving it is often recounted that the car seems to be an extension of the body schema. Thus, an experienced driver doesn't need to think about or be explicitly attentive to the details of driving or the car's movements. In some instances one arrives at one's destination without a recollection of the actual details of the drive — the driving body has been on automatic pilot so to speak. To some extent this high degree of automatic control in the case of driving is facilitated by visual proprioception. Lee and Aronson (1974) point out that "the proprioceptive function of vision seems apparent enough in driving a vehicle; the driver clearly uses visual information about his and the vehicle's movement to guide the vehicle" (p. 529). IW drives and enjoys it. It seems effortless to him in comparison to walking. He reports that it is easier for him to drive 300 or 400 miles in a car than to stop and refuel. Driving actually allows him relative relaxation of attention to his bodily movement. He maintains his posture by "freezing" in place. He needs only to keep his hands within the visual field (the driving controls in his vehicle are all operated by hand), and he is assisted in a high degree by visual proprioception — the landscape rushing by — in incorporating the car into his system of motor control. IW has to think hard about walking; but not as hard about driving.

The interior of the automobile is also a much safer environment for IW than most he experiences, for his commitment to walking has led to risk. He requires a well-defined personal space surrounding him to avoid the danger of unexpected movements by others. An unexpected touch or bump can easily upset his balance. His personal boundaries are maintained visually; he constantly monitors the positions of his limbs relative to external objects.

IW's case also suggests that the body schema, and not just the body image, plays an important role in constituting a sense of body ownership. IW reports that when the neuropathy first manifested itself he felt alienated from his body. Although he still had a visual perceptual awareness of his body, and could conceptually understand that it was his own body, the fact that he could not control bodily movement, may explain his sense of alienation. Stern (1985) contends that volition is the most important invariant in the sense of selfhood. Motor activity is often accompanied, if not by a conscious sense of volition, then at least by the lack of a sense of helplessness or want of control. If one loses control over motor activity, one also gains a sense of helplessness (that is, loses a sense of authorship) over one's actions.

This suggests that the control of one's body and bodily movement and the accompanying emotional value of this control play an important role in experiencing the body as owned. It seems reasonable to suggest that a subject's sense of owned embodiment is sometimes disrupted by a lack of control over the body when proprioception and the body schema fails. A normal, unalienated body image thus depends on certain body-schema processes that enable us to produce and control movement. In the first phase of the illness, IW lacked control over movement. Only after he gained back that control was he able to reconstruct the felt sense of owned embodiment. So even if the body schema functions in an anonymous way, it lends some support to a sense of owned embodiment.[10]

The conceptual distinction between body image and body schema seems to be a productive one in analyzing this case. It helps to clarify IW's motor difficulties. In turn, IW's case throws some light on normal and abnormal relations between body image and body schema. Because IW's movements are controlled more by his conscious attention than by a prepersonal body schema, they indicate extraordinary, perhaps uniquely high degrees of intentionality and personal control. They also reflect a number of limitations with regard to the holistic nature of movement and its experiential integration with the surrounding world.

References

Adame, D.D., Radell, S.A., Johnson, T.C., and Cole, S.P. (1991). Physical fitness, body image, and locus of control in college women dancers and non-dancers. *Perceptual and Motor Skills*, *72*, 91–95.

Assaiante, C., Amblard, G., and Carblanc, A. (1988). Peripheral vision and dynamic equilibrium control in five to twelve year old children. In B. Amblard, A. Berthoz, and F. Clarac (Eds.), *Posture and gait: Development, adaptation and modulation* (pp. 75–82). Amsterdam: Excerpta Medica.

Bernett, M.E., Cole, J.D., McLellan, D.L., and Sedgwick, E.M. (1989). Gait analysis in a subject without proprioception below the neck. *Journal of Physiology*, *417*, 102.

Brandt, T. (1988). Sensory function and posture. In B. Amblard, A. Berthoz, and F. Clarac (Eds.), *Posture and gait: Development, adaptation and modulation* (pp. 127–136). Amsterdam: Excerpta Medica.

Cash, T.F., and Brown, T.A. (1987). Body image in anorexia nervosa and bulimia nervosa: A review of the literature. *Behavior Modification*, *11*, 487–521.

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

Cole, J.D., and Katifi, H.A. (1991). Evoked potentials in a subject with a large fibre peripheral neuropathy. *Electroencephalography and Clinical Neurophysiology*, *80*, 103–107.

Cole, J.D., Merton, W.L., Barrett, G., Katifi, H.A., and Treede, R-D. (1995). Evoked potentials in a subject with a large fibre sensory neuropathy below the neck. *Canadian Journal of Physiology and Pharmacology*, *73*, 234–245

[10]Oliver Sacks remarks (in the "Forward" to Cole, 1995) that the case of IW "shows how such a peripheral disorder can have the profoundest 'central' effects on what Gerald Edelman called the 'primary consciousness' of a person: his ability to experience his body as continuous, as 'owned,' as controlled, as his. We see that a disorder of touch and proprioception, itself unconscious, becomes, at the highest level, a 'disease of consciousness' " (xiii).

Cole, J.D., and Paillard, J. (1995). Living without touch and peripheral information about body position and movement: Studies upon deafferented subjects. In J. Bermúdez, A. Marcel, and N. Eilan (Eds.), *The body and the self* (pp. 245–266). Cambridge, Massachusetts: MIT Press.

Cole, J.D., and Sedgwick, E.M. (1992). The perceptions of force and of movement in a man without large myelinated sensory afferents below the neck. *Journal of Physiology, 449*, 503–515.

Crook, J. (1987). The nature of conscious awareness. In C. Blakemore and S. Greenfield (Eds.), *Mindwaves: Thoughts on intelligence, identity, and consciousness* (pp. 383–402). Oxford: Basil Blackwell.

Denny–Brown, D., Meyer, J.S., and Horenstein, S. (1952). The significance of perceptual rivalry resulting from parietal lesion. *Brain, 75*, 433–471.

Fisher, S. (1964). Sex differences in body perception. *Psychological Monographs, 78*, 1–22.

Fisher, S. (1972). Body image. In D. Sills (Ed.), *International encyclopedia of the social sciences*, Volume 2. New York: Collier–Macmillan.

Fisher, S., and Cleveland, S.E. (1958). *Body image and personality*. Princeton: D. van Nostrand.

Forget, R., and Lamarre, Y. (1995). Postural adjustments associated with different unloadings of the forearm: Effects of proprioceptive and cutaneous afferent deprivation. *Canadian Journal of Physiology and Pharmacology, 73*, 285–294.

Gallagher, S. (1986). Body image and body schema: A conceptual clarification. *Journal of Mind and Behavior, 7*, 541–554.

Gallagher, S. (1995). Body schema and intentionality. In J. Bermúdez, A. Marcel, and N. Eilan (Eds.), *The body and the self* (pp. 225–244). Cambridge, Massachusetts: MIT Press.

Gallagher, S., and Meltzoff, A.N. (in press). The earliest sense of self and others: Merleau–Ponty and recent developmental studies. *Philosophical Psychology*.

Gardner, R.M., and Moncrieff, C. (1988). Body image distortion in anorexics as a non-sensory phenomenon: A signal detection approach. *Journal of Clinical Psychology, 44*, 101–107.

Garner, D.M., and Garfinkel, P.E. (1981). Body image in anorexia nervosa: Measurement, theory, and clinical implications. *International Journal of Psychiatry in Medicine, 11*, 263–284.

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

Gurfinkel, V.S., and Levick, Y.S. (1991). Perceptual and automatic aspects of the postural body scheme. In J. Paillard (Ed.), *Brain and space* (pp. 147–162). Oxford: Oxford University Press.

Head, H. (1920). *Studies in neurology*, Volume 2. London: Oxford University Press.

Head, H. (1926). *Aphasia and kindred disorders of speech*, Volume 1. Cambridge: Cambridge University Press.

Head, H., and Holmes, G. (1911–12). Sensory disturbances from cerebral lesions. *Brain, 34*, 102–245.

Jouen, F. (1988). Visual-proprioceptive control of posture in newborn infants. In G. Amblard, A. Berthoz, and F. Clarac (Eds.), *Posture and gait: Development, adaptation, and modulation* (pp. 13–22). Amsterdam: Excerpta Medica.

Lackner, J.R. (1988). Some proprioceptive influences of the perceptual representation of body shape and orientation. *Brain, 3*, 281–297.

Lee, D.N., and Aronson, E. (1974). Visual proprioceptive control of standing in human infants. *Perception and Psychophysics, 15*, 529–532.

Lee, D.N., and Lishman, J.R. (1975). Visual proprioceptive control of stance. *Journal of Human Movement Studies, 1*, 87–95.

Melzack, R. (1989). Phantom limbs, the self and the brain. *Canadian Psychology, 30*, 1–16.

Meltzoff, A. (1990). Towards a developmental cognitive science: The implications of cross-modal matching and imitation for the development of representation and memory in infancy. In *The development and neural bases of higher cognitive functions*, Volume 608 of the *Annals of the New York Academy of Sciences* (pp. 1–37). New York: New York Academy of Sciences.

Neisser, U. (1976). *Cognition and reality: Principles and implications of cognitive psychology*. New York: W.H. Freeman.

O'Shaughnessy, B. (1995). Proprioception and the body image. In J. Bermúdez, A. Marcel, and N. Eilan (Eds.), *The body and the self* (pp. 175–203). Cambridge, Massachusetts: MIT Press.

Parsons, L.M. (1990). Body image. In M.W. Eysenck (Ed.), *The Blackwell dictionary of cognitive psychology* (p. 46). Oxford: Blackwell Reference.

Phillips, C. (1986). *Movements of the hand.* Sherrington Lectures, XVII. Liverpool: Liverpool University Press.

Poeck, K., and Orgass, B. (1971). The concept of the body schema: A critical review and some experimental results. *Cortex, 7,* 254–277.

Powers, P.S., Schulman, R.G., Gleghorn, A.A., and Prange, M.E. (1987). Perceptual and cognitive abnormalities in bulimia. *American Journal of Psychiatry, 144,* 1456–1460.

Roll, J-P., and Roll, R. (1988). From eye to foot: A proprioceptive chain involved in postural control. In G. Amblard, A. Berthoz, and F. Clarac (Eds.), *Posture and gait: Development, adaptation, and modulation* (pp. 155–164). Amsterdam: Excerpta Medica.

Roll, J-P., Roll, R., and Velay, J-L. (1991). Proprioception as a link between body space and extra-personal space. In J. Paillard (Ed.), *Brain and space* (pp. 112–132). Oxford: Oxford University Press.

Rothwell, J.C., Thompson, P.D., Day, B.L., Dick, J.P.R., Kachi, T., Cowman, J.M.A., and Marsden, C.D. (1987). Motor cortex stimulation in man. 1. General characteristics of the EMG responses in different muscles. *Brain, 110,* 173–190.

Ruggieri, V., Milizia, M., Sabatini, N., and Tosi, M.T. (1983). Body perception in relation to muscular tone at rest and tactile sensitivity to tickle. *Perceptual and Motor Skills, 56,* 799–806.

Saadah, E.S.M., and Melzack, R. (1994). Phantom limb experiences in congenital limb-deficient adults. *Cortex, 30,* 479–485.

Schilder, P. (1935). *The image and appearance of the human body.* London: Kegan, Paul, Trench, Trubner and Co.

Shontz, F.C. (1974). Body image and its disorders. *International Journal of Psychiatry in Medicine,* 5, 461–472.

Stern, D. (1985). *The interpersonal world of the infant.* New York: Basic Books.

Sternman, A.B., Schaumberg, H.H., and Asbury, A.K. (1980). The acute sensory neuropathy syndrome: A distinct clinical entity. *Annals of Neurology, 7,* 354–358.

Volpe, B.T., LeDoux, J.E. and Gazzaniga, M.S. (1979). Spatially oriented movements in the absence of proprioception. *Neurology, 29,* 1309–1313.