

BODY SCHEMA AND BODY IMAGE - A DOUBLE DISSOCIATION IN DEAFFERENTED PATIENTS

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INTRODUCTION

The concept and term of "**Body Image**" (l'image de soi, Lhermitte, 1937) has frequently been used interchangeably in neurological and psychological studies with that of "**Body Schema**" (Körperschema) (Schilder, 1935) thus leading to enduring methodological and conceptual confusions in various fields.

In a recent review, Shaun Gallagher (1992) stressed the serious implications that the terminological and conceptual confusions related to body image and body schema have had for the study of body experience and personality in the psychoanalytical and phenomenological literature. He rightly points to the relationship between consciousness and these body concepts as the main unresolved issue in this controversial field. In suggesting that the first step in working out a distinction between body image and body schema is to distinguish between a conscious awareness of one's own body and a non conscious performance of the body, Gallagher meets the criticisms that we addressed nearly 20 years earlier (following to Oldfield, & Zangwill, 1941/42) to the neurologists in a meeting devoted to the problem of selfconsciousness (Paillard, 1975). We vigorously denounced the perduring confusion between these basic concepts in the neurological and psychological literature in spite of the very clear distinction that was initially made by Head and Holmes (1912), between: 1) the " Postural Schema " as " A combined standard against which all subsequent changes of posture are measured ... *before the changes of posture enter consciousness*" 2) the " Superficial schema " as a central mapping of somatotopic information derived from the tactile information and 3) the " Body Image " as an internal representation *in the conscious experience* of visual, tactile and motor information of corporal origin. We also appealed to expanding efforts for establishing the biological identity and validity of such a distinction.

At that time, widespread interest was generated by the discovery of the existence of " two visual systems ", one for object perception and one for spatial localisation. The study initially separated the role of collicular structures in orientation and localisation from that of cortical areas in the perceptual discrimination and categorisation of visual forms. It was later established by neuroanatomical, neurophysiological and neuropsychological studies (Ungerleider & Mishkin, 1982) that both systems were corticalized in primates and man leading to the now classical functional segregation between the "what" and "where" systems with their underlying neural networks in the temporal and the parietal cortex respectively. We then proposed (Paillard, 1975, 1980) to extend this

functional dichotomy so successfully introduced in the study of visual function, to kinæsthetic information in the body space. Thus, We suggested that the location of body parts in a *body schema* (a "where" problem in the body space) could be differently processed in the CNS than the perceptual identification of the body features in a *body image* (a "what" problem). Hence the position of body segments and the skin areas might be either registered as location in a sensorimotor mapping of the body space (and able to direct a reaching movement) or perceived as position in the perceptual representation of a body image. Then we assumed that proprioceptive information is obviously necessary for updating the postural body frame (or schema), whereas exteroceptive multimodal information, mainly visual, underpins the central representation and percept of the body image (Paillard, 1982, 1997; Cole & Paillard, 1995).

Concerning now the problem of consciousness put forward by Gallagher (1992) as the crucial issue to be solved for grounding a clear distinction between *body schema* and *body image* an other important discovery made around the seventies that is worthy of our attention. It concerns the existence of residual visual capacities observed in monkeys rendered sightless by bilateral ablation of their cortical visual field (Humphrey & Weiskrantz, 1967) and later, studies of the blind visual field in human "hemianopsic" patients suffering from retro-chiasmatic lesions in their visual pathways. (Pöppel *et al.*, 1973; Weiskrantz *et al.*, 1974; Perenin & Jeannerod, 1975). This residual capacity manifests itself in a rather strange aptitude in animals as in humans, both of whom being capable of correctly pointing (in forced choice condition) in the direction of a luminous target that they cannot see. This ability to locate and reach a non perceived visual target has been since confirmed and coined by Weiskrantz (1989) as the "blind sight" phenomenon. Thus the experimental assessment of a pathological dissociation of the process that leads to the conscious perception and verbal identification of an object in view and of those that allow its localisation in the reaching space opened new stimulating ways for the scientific investigation of conscious processes. (Schacter *et al.*, 1988)

Despite early interest in observing the dissociation between the localisation and the perceptual identification of stimuli (reviewed in Halligan *et al.*, 1995) there have been very few detailed accounts concerning this topic in the recent literature. As rightly stressed by Bender (1952, p.55) " Ordinarily when a patient experiences a sensation, we take for granted that he can locate the site of the stimulation. We seldom request the patient to indicate the point of stimulation because it is generally assumed that the ability to perceive is associated with the ability to localise ". In their seminal paper, Head and Holmes (1911) used the term "atopognosis" to describe the failure observed in certain patients to locate a stimulated area within their body space. They specified that, depending on the subjects the effects could range from relatively small tactile mis locations to total absence of knowledge of where the patient has been touched.

Herewith we wish to present two clinical observations that seem relevant to us in corroborating the existence of such a functional segregation in the processing of tactile information in the body space They concern two clinical cases which offer a contrasting view of the consequences of deafferentation whether of central

or of peripheral origin, in their ability to perceive and to locate a tactile stimulus on the skin surface of their body. The first concerns a stroke patient, centrally deafferented who offered the first clinical observation of an equivalent of " blind sight " in the tactile modality, i.e. a location without perception (Paillard *et al.*, 1983). The second patient suffering from an extensive neuropathy shows the converse dissociation i.e. a capacity to detect and verbalise the perceived location of the stimulus on her body but failing to reach the stimulated site when her vision is blocked (Paillard, 1997).

LOCALISATION WITHOUT SENSORY DETECTION: A CLINICAL CASE OF CENTRAL DEAFFERENTATION

R.S. (now aged 66) was a 52 year-old, right handed woman when referred to the Neurological Hospital, Lyon, France (Dr François Michel) for headache and reading difficulties. An arteriovenous malformation on the dura matter around the left occipital lobe was revealed by a carotid angiogram. Following a successful obstruction of the nourishing artery by catheterization of the external carotid artery,

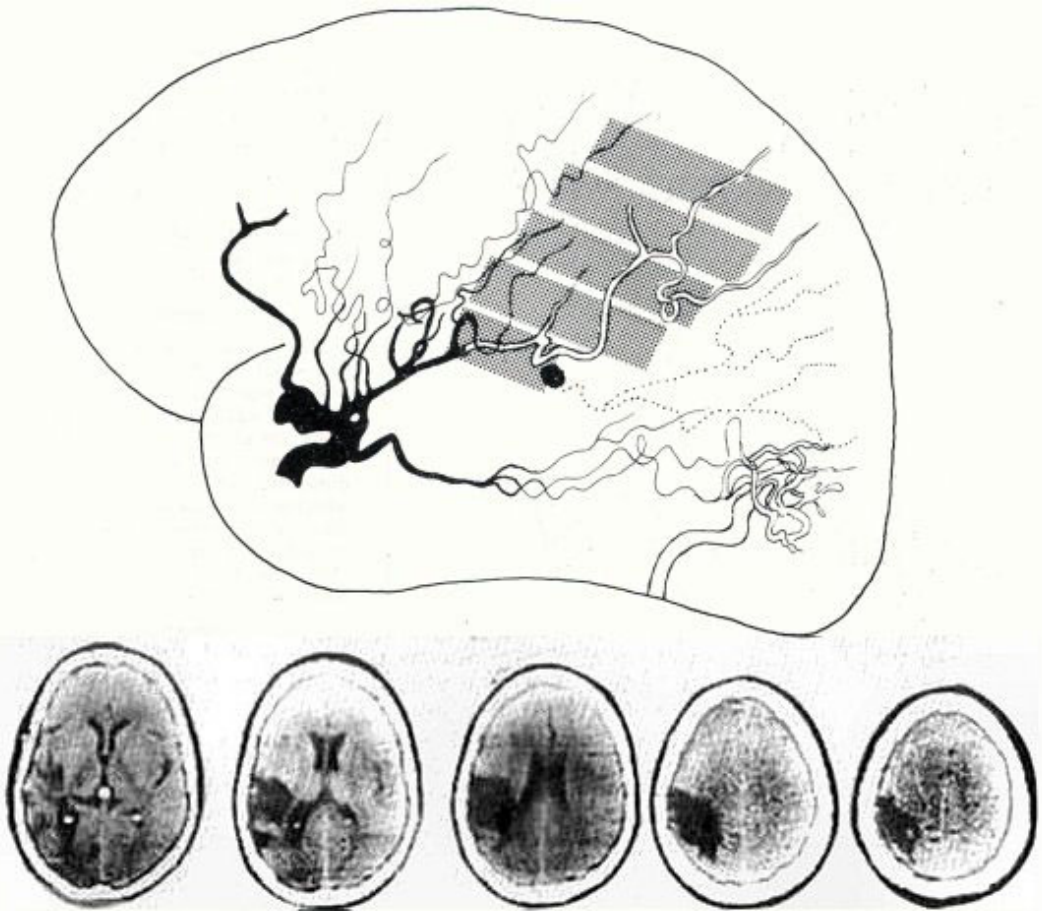


Figure 1. Reconstruction of lesion according to five *computed tomographic scan* slices at bottom. In the drawing of the left hemisphere, black lines indicate normal arteries (anterior cerebral artery not completely drawn for sake of clarity); dotted lines, revascularisation through dorsal arteries; while lines indicate, thrombotic parietal artery. In occipital region, arteriovenous angioma is shown. (From Paillard *et al.*, 1983).

residual thrombotic material unfortunately escaped from the tip of the needle and thus eventually created an obstruction in the left posterior parietal artery. As a result of this accident, a softening of the left parietal area occurred, including as shown by CT scan, areas 1, 2, 3, 5, 40 and 43 of the post-central gyrus. (see Figure 1).

She presented clinically incomplete right side hemianopia, hemianacousia, and right side hemianesthesia persistent after several years and associated with neurological syndromes that showed rapid improvement after few weeks. In spite of the extent of the lesion, no sign of optic ataxia was observed in the intact visual field. Very severe sensory deficit in the distal part of the left arm below the elbow is noted (the patient may cut or burn herself without noticing it). Static tactile stimulations are undetected. Joint position sense, thermal and pain sensations were absent. In contrast, there was very little motor deficit under visual guidance. Tendon reflexes are normal and symmetrical.

Electrophysiological tests confirmed the absence of somæsthetic evoked potentials after stimulation of the right index and middle fingers whereas M1, M2 and M3 EMG responses to sudden stretch of the deafferented wrist were normal.

Results

The centrally deafferented patient (R.S.) (see Figure 2) was unable to detect and to perceive any static tactile stimulations delivered to various sites on her right

lower arm and hand, thus fails to locale verbally the spatial position of the stimulated area. Moreover she was able to point accurately and without comment to the point stimulated on her intact hand with her deafferented but normally efferented hand.

In the reverse condition, when asked to point with her intact arm on the deafferented hand, she followed the instructions automatically for the first few trials and then spontaneously interrupted the examination to express her astonishment. Her comments, despite traces of residual dysphasia, were very apposite, as shown in the following three samples:

"But, I don't understand that. You put something there; I do not feel anything and yet I got there with my finger. How does that happen?"

"I would like to understand, because eventually, if I do not feel I should not be able to feel it either. Why do I see it? I hear that one"

"Well, I cannot say what it is, but I know that there is a place that you are going to. But it's such little thing, if you like. It's so tenuous, tenuous....."

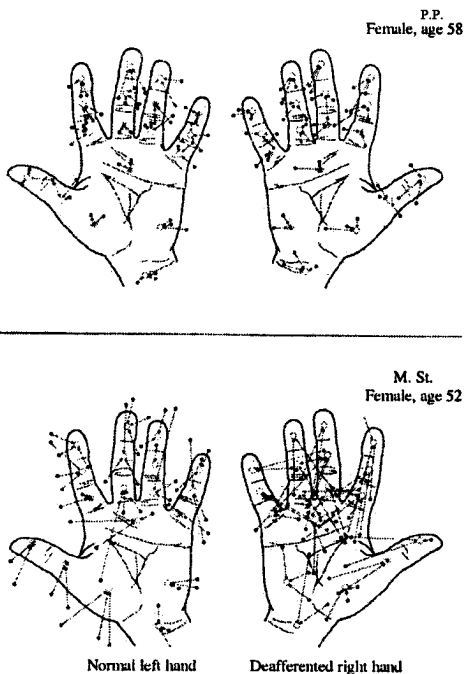


Figure 2. Top: Pointing performance by centrally deafferented patient (R.S.) on her left normal hand (left) and on her deafferented hand (right). Three stimulations were randomly distributed on each of 18 positions marked with circle. Black points and arrows indicate amount and direction of errors.

Bottom: Corresponding pointing performance of control subject of same age and sex (From Paillard *et al.*, 1983).

feelings and conscious experience when attempting to respond to tactile stimulation of her deafferented arm. Her first comment explicitly introduced the notion of pure localisation without any definite content. Her second comment reflects the peculiarity of her experiment and her resort to multimodal expression of her feelings as seeing or hearing... Her third comment emphasises the motor support for her localisation responses and the tenuous and undescribable nature of these unfamiliar sensations associated with them.

Overall, these comments offer striking similarities to those of patients with "blind sight" as reported by Weiskrantz, (1980). Despite her inability to detect static pressure on her skin, this patient was able to, spontaneously (without the necessity of resorting to the forced choice procedure) and much to her own surprise, point approximately to the locus of stimulation: a clear localisation without sensory detection.

Discussion

Since the publication of this case (Paillard *et al.*, 1983), two similar cases of "blind touch" have been published. The most clinically comparable to our case is the one of Rossetti *et al.*, (1995). they present the case of a patient with a lesion of the thalamus who was completely anaesthetised on his right side. Unable to detect and describe a tactile stimulus applied to his affected right arm, he could direct his normal left hand, when so instructed, toward the specific right hand site where the stimulus had been applied ('blind touch'). Strikingly, he fails to indicate where he has been touched by pointing on a picture of an arm and to name the stimulus location on his body in contrast with what we have observed in peripherally deafferented patient (see below).

Similar results were also obtained in the blindfolded patient for localising her unfelt fingertip by pointing with the thumb (what the authors name a 'blind proprioception') thus confirming an earlier observation by Volpe *et al.*, (1979).

Rossetti *et al.*, (op. cit.) pointed rightly to the fact that we did not investigate the verbal report of our patient in a forced choice paradigm in order to discard a possible covert detection of the stimulus. Interestingly, they were not able to observe any significant performance of their patient in the verbal forced-choice for stimulus location thus interpreting the result as a dissociation between a pragmatic system responsible for the stimulus driven pointing and a semantic system responsible for verbally depicting the same stimulus location.

Considering the neuropsychological case studies showing that brain lesions can produce reciprocal dissections between object identification (what is the object) and object-oriented action (how to direct a movement to the object) they suggest a dissociation between a 'where' system and a 'how' system for tactile and proprioceptive stimuli. They conclude however, that this dissociation is similar to that already demonstrated in the visual modality when "individuals cannot consciously recognise visual objects (what) but remain able to realise object oriented actions (how). In our general discussion we have further comments on this interesting conclusions(see below).

The second reported case is that of Brochier, Habib and Brouchon (1994). It

concerns the observation of a patient suffering from a complete loss of somæsthetic sensibility in his left arm and hand resulting from a clearly delineated region of the primary sensory area who showed a surprising sensorimotor control of his anaesthetised hand. Two months after his CVA he exhibited in pointing with his thumb in blindfolded conditions to designated fingers of his deafferented hand a performance almost similar as that obtained with his normal hand. The authors discussed the possible contribution of a presumed covert processing of somæsthetic information intervening in an unconscious sensorimotor control of the hand movements. Following our own conclusions they also suggest a parallel organisation of somæsthetic information processing very close to that envisaged in the visual modality. Additionally they put forward an hypothesis concerning the neural support of such a dissociation in the tactile modality. We will come back to this point in our general discussion.

Such a clear demonstration of the existence of localisation without detection obviously raised the possibility that the converse functional dissociation namely that detection without localisation might occur. Our peripherally deafferented patient meets precisely this expectation.

SENSORY DETECTION WITHOUT LOCALISATION: A CLINICAL CASE OF PERIPHERAL DEAFFERENTATION

G.L. is a 50 year old female patient (followed by Dr.Y. Lamarre, Hotel Dieu, Montréal) who has been deafferented for the last 19 years following a *Guillain-Barré* and a second episode (4 years later) of *polyneuropathy* affecting selectively the large myelinated sensory fibres with an intact motor system.

She presents clinically a total loss of touch, vibration, pressure and kinæsthetic senses below the nose and no tendon reflexes in the four limbs. Pain and temperature sensations are present suggesting a selective impairment of the large diameter peripheral sensory myelinated fibres.

Electrophysiological tests confirmed that the motor fibres were not affected and motor nerve conduction was normal in the four limbs. The H reflex was absent in the legs. No cortical evoked response was observed by electrical stimulation of peripheral nerves of either arm. A sural nerve biopsy revealed that nervous fibres larger than 6.5 microns represented only 1.6 % of the total number of myelinated fibres (N= 1,600) (Cooke *et al.*, 1985; Forget, 1986).

Observations and experimental investigations

G.L. is entirely dependant on vision to locate her body and the relative position of it segments in space. When prevented for looking at her right arm for instance and asking her to match the position of both arms while looking at her left arm, she can do it only if the right arm remains in the last position that she has been able to see. If, however, the unseen arm is passively displaced by the experimenter she becomes completely lost and disoriented. Deprived of her main source of kinæsthetic information (from muscular proprioception, skin and joint receptors), GL still have a preserved contingent of small sensory fibres providing her with thermal and pain sensation (and possibly also some faint information about skin

rubbing carried out through C fibres (Lamarre, personal communication). Thus, in blindfolded condition, she can clearly detect pricking or thermal stimulation delivered to her skin surface.

She seems to be able to use thermal feeling as a suppletive proprioceptive information locating usually her cooler hands on top of her warmer thighs. Similarly, she spontaneously comments that she likes to have her arms uncovered to be able to know without looking at, its location when being in contact with her warmer body. I remember my first contact with GL. She had her naked arms lying on a formica tabletop. After asking her to close her eyes, I slowly moved her right arm on the table and inquired about what she felt. Surprisingly she immediately answered "you have moved my right arm". Intrigued by this unexpected reaction from the part of a presumably deafferented person, I tried to inquire about the more precise content of her feeling. Then she explained very clearly that the table surface was cool and she thereby felt the shift of her arm (the above mentioned mecanoreceptive C fibres might also have contributed).

Overall, her knowledge of her initial arm position greatly improves the accuracy of their pointing movement toward visual target. We noticed that in the many experiments on pointing done with her, she repetitively looked at her starting position while waiting the next visual target.

When using pricking or cold stimuli randomly distributed on various places on her body surface, she proves to be perfectly able to design verbally the location of the stimulation on her body parts and additionally, to be accurate when asked to point visually on a body sketch. When however requested to point with her right hand towards the stimulated place on her body, several situations have to be considered.

When sitting with both naked arms lying on the table in a normal resting position, she moves slowly and awkwardly in the direction of the stimulated arm, and then seems to be able to feel when the contact is established (thermal clues ?) and then she sometimes begins to move on the skin surface toward the stimulus place (mecanoreceptive fibres). When, however, the final contactual information is prevented by interposition of a cardboard covering the arm, her performance deteriorates even more rapidly as the return to the initial position is no longer visually controlled.

In order to try to evaluate the role of the visual body representation and of some residual somæsthetic clues we carried out a series of three well controlled experiments as described below.

1) 12 skin spots were marked on the left side of her body (see Figure 3). Cold stimulations were applied randomly three times on each spot. After each stimulation the patient was asked to designate the site of each stimulation verbally and by pointing on a body sketch.

2) On the dorsal and ventral skin areas of her hand lying on the table at 45° of the frontal plane, 12 skin spots were marked. Three cold stimulations were randomly applied on each spots. Then three situations were tested :

a) visual pointing after each stimulation on a body sketch; b) right hand pointing in blindfolded conditions to the left hand (with a readjustment of the initial position of

blindfolded conditions to the left hand (with a readjustment of the initial position of the pointing hand after each trial). C) right hand pointing to the left hand with vision.

3) In order to evaluate the role of the memorised visual representation of the body position. Three skin spots were marked on the dorsal left forearm and randomly stimulated by pricking. The target arm was rigidly locked to a moving platform allowing its passive rotation around the elbow without the knowledge of the patient who has never reported to have been aware of any change of her arm position during the experiment. The orientations of the target arm were randomly changed at each trial (20° , 45° and 70°). The initial position of the pointing arm

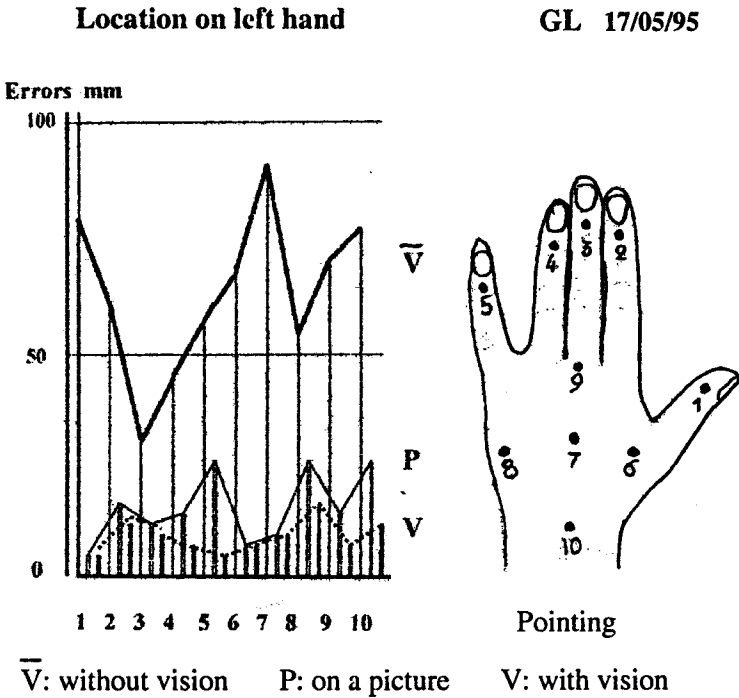


Figure 3. Pointing by peripherally deafferented patient (G.L.) to cold stimulation of 10 areas of her dorsal left hand in 3 conditions: with vision (V); without vision (\bar{V}); and on a picture of the hand (P). Each point of the diagram (left) represents mean error (in mm) of 3 pointings at each of the 10 sites located on the hand sketch (right). Accuracy on a hand sketch is slightly worse than with vision allowing a final correction. In contrast, the performance is greatly impaired when vision is prevented. See comments in the text.

was visually calibrated before every trial.

The main results of the two first experiments are illustrated on the Figure 3 and can be summarised as follow: verbal identifications of the stimulated body parts are generally excellent. The accuracy with which stimulated positions are designated on a body picture is not significantly different from that observed with a direct visual pointing of the body sites. In contrast the accuracy of pointing with the contralateral hand, in blindfolded condition drops dramatically, preserving however a crude orientation of the reaching hand toward the hand position.

Accordingly, the third experiment clearly shows that, whatever the orientation of the target arm passively moved by the experimenter, pointing trajectories (starting from the same position visually recalibrated at each trial) ended around skin spots referred to the memorised last seen position of the arm (45°), thus asserting the role of a visual frame of reference for guiding the pointing movements (See Figure 4).

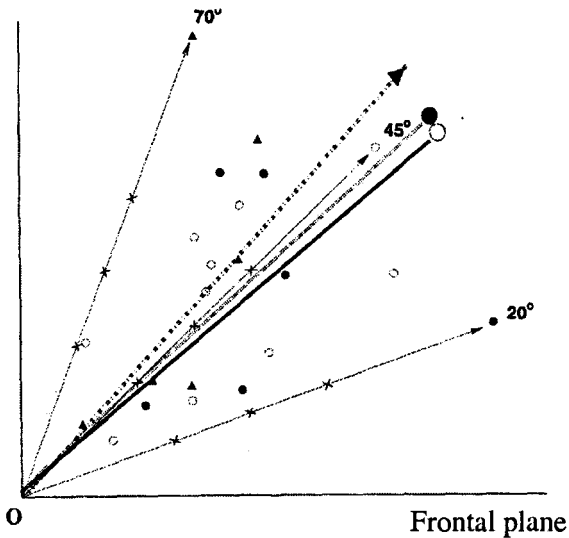


Figure 4 Pointing by peripherally deafferented patient (G.L.) at pricking stimulation on her left arm, in blindfolded conditions. The orientations of the target arm were randomly changed (20° , 45° and 70° from the frontal plane) with rotation around the elbow joint (O). The results show that, whatever the orientation of the target arm, pointing trajectories (starting from the same position visually recalibrated at each trial) ended around skin spots referred to the memorised last seen position of the arm (45°).

Discussion

The results obtained with this patient in a study of spatial frames of reference (Blouin *et al.*, 1993) showed convincingly that she is greatly impaired in her ability to point at luminous targets in complete darkness and without vision of her arm (i.e., in an egocentric condition that forces her to relate the target to a body-centered frame of reference). Conversely, the presence of a structured environment allows her to use an exocentric system of co-ordinates, resulting in the production of accurate goal-directed movements.

An egocentric frame of reference is a dynamic structure that stems from continuous updating of the relative positions of the body segments by way of static and dynamic proprioceptive signals, tuning the motor commands for spatially oriented movements. Gaze anchoring on target allows referral of the target orientation to the eye position in the head. The head itself may serve as an egocentric frame of reference to which the trunk and the body segments also have to be referred, mainly via the neck afferent information, so that the initial position of the moving arm can be correctly evaluated. Obviously, such a system is not completely accessible to deafferented patients. When goal-directed movements are performed in a structured environment, the body itself can be referred to the

stabilised environment, and is then calibrated in the visual map, reducing the updating role of proprioceptive input.

We may conclude from this data that our patient, unable to update proprioceptively her postural schema, cannot calibrate the location of the tactile stimulus in her body schema. Hence her failure to direct a pointing movement toward the right place in a body-centered co-ordinate system when her vision is prevented. Consequently, she is obliged to resort to the transaction of a memorised visual representation of her body and the relative positions of their mobile segments. The perceived tactile stimulus is then located within a memorised "body image" and can be verbally designed. The way in which such a body image may allow the programming of movements directed to target-goal remains an open question. Obviously the knowledge of the initial position of her body (real or memorised) is mandatory for a successful reaching. This requires the mediation of a body representation allocentrically referred in a stable visual surrounding.

The case recently described by Halligan *et al.*, (1995) of a stroke patient who in spite of a relatively intact verbally reported cutaneous detection shows frequent failure in pointing accurately to the stimulus place. Interestingly, this case is presented as a converse functional dissociation of that observed in our centrally deafferented patient RS. The authors stress the fractionation of the patient's subjective experience as "the most intriguing aspects of this dissociation". RS spontaneously noticed that she was capable of localising without feeling what must have been detected implicitly and the Halligan's patient spontaneously notice that he was incapable of localising what he had detected explicitly.

We are obviously trying to develop the same kind of arguments with our peripherally deafferented patient who seems to offer a much cleaner clinical context for such a comparison. A critical reappraisal of the potential neural structures involved in these functional dissociations according to the variety of the clinical cases now available, will be tentatively undertaken in the general discussion. The most compelling evidence for a double dissociation seems, in our view, resides in the comparison between the relatively clean centrally hemideafferented patients of Rossetti *et al.* (op. cit.) and our similarly clean peripherally deafferented case. The others cases are nevertheless also worth consideration for a better understanding of the nervous mechanisms involved in these functional dissociations.

GENERAL DISCUSSION

The two cases reported here provide evidence for the double dissociation of detection and localisation of tactile stimuli.

The *centrally deafferented patient*, unable to detect consciously the presence of a tactile stimulus is nevertheless able (much to her own surprise ...) to direct her pointing hand to the stimulated body place in her *body schema*.

In contrast the *peripherally deafferented patient*, although unable to direct her pointing hand toward specific loci on the stimulated body side (when her vision is blocked), is nevertheless capable of mediating (verbally or by pointing on a body picture) a rather precise somatotopic localisation of her conscious tactile detection

in her *representational body map* (*her body image*).

The current assumptions regarding the close relationship between the conscious awareness of tactile stimulation and the localisation thereof are thus compellingly challenged by this data. Whether this functional segregation, now clearly dissociated by pathology, may be dependent on separate neural networks is still a debated question.

1). As far as the location process is concerned, we suggested (Paillard, 1991b) to complement the, by now, well documented distinction between the "what" and "where" systems with the necessary dissociation between the "What" and the "How to use it", on the one hand, and the "Where" and the "How to get there", on the other hand. The last distinction (also adopted by Rossetti *et al.*, 1995) in discussing the performance of their hemi-anaesthetized patient) fits with the more general distinction we gave earlier between two processing modes of spatial relationships (Paillard, 1987; 1991a).

The basic assumption of our argument was that a *sensorimotor* mode of processing spatial information coexists with a *representational* mode and that both modes are organising and generating their own mapping of space (Paillard, 1987).

The *sensorimotor mode* concerns mainly that part of the physical world to which the organism is attuned by virtue of its basic sensorimotor apparatus. Local sensorimotor instruments maintain direct dialogues with that world and thus contribute to the continuous updating of a body-centred mapping of extra-corporal space where objects are located and to which actions are directed.

The *representational mode* derives from neural activities, which explore and consult internal representations of the physical environment, that are embodied in memory stores. They includemental representations of local maps, spatial relationships of routes relative to landmarks, relative positions between objects, and the position of the body itself in relation to its stationary environmental frame.

The question then arises as to whether the two processing modes operate in parallel, each using its own neural circuitry and generating its own mapping of space in two fundamentally different frames of reference, respectively body- and environmentally-centered.

How far can we extend this dissociation to the body space itself? Actually, the body can be considered both a) as a body-centred reference for directing our actions in the external space (but also for locating skin sites at hand reach or for attracting targets for our gaze), and b) as one object perceived as situated in the external space and referred to the stable visual environment. The perception of tactile clues are thus object-centered and the stimuli located within the represented "body image" ? (Paillard 1980, 1982, 1991a).

Thus, now returning to the dissociation between "knowing where" and "knowing how to get there", the primary distinction is to be made between a perception of the body space as interrelated position in the direct or memorised central mapping of the body shape and a flexible repertoire of motor programmes which define the action to be performed in order to reach the target locus within the superficial schema of the skin surface. More generally, the problem is to consider how far the conscious perception of space can be dissociated from a motor

appropriation of space (Paillard, 1991b).

2) When considering the detection process we immediately confront the intriguing problem of consciousness and the neuroscientist faces a forest of still unanswered question marks (Lahav, 1993). The considerable expansion of the representational capacities of the human brain, subsequent to the development of linguistic skills, might possibly take precedence over the basic sensorimotor capacities and thereby mask the action-oriented roots of the way in which spatial information is processed including those related to the body space. Undoubtedly, many abstract representations of space do exist in humans that are not shared by other species, with various degrees of independence from action in space. Notwithstanding the improvement of attentional and intentional control together with the emergence of self-awareness, which contributes to the wondering, unfold of human brain capacities. These facts are reflected in the expanding resources of man's spatial cognition and is indirectly illustrated by the variety of spatial disorders studied in neuropsychology (Hecaen & Ajuriaguerra, 1952; Denis, 1976; De Renzi, 1982).

More specifically, the surprising variety of the numerous disorders described in pathology under the heading of "autopagnosia" are directly related to the many facets of the body representation in our cognitive experience (de Renzi & Scotti, 1970; Ogden, 1985). Moreover, the definition gave by de Renzi (de Renzi, 1982, p.200) to this syndrome described as "an inability to point on verbal command to one's body part as well as those of the examiner or of a human picture" is open to a possible confusion between the implicit basic sensori-motor capacity of the body schema and the multiple processing ways of the body image at a cognitive level.

Be that as it may, the old Piagetian distinction (Piaget, 1937) between the "savoirs" and the "savoirs faire", now definitely credited to the Ryle's distinction (Ryle, 1949) between "knowing what" and "knowing how" (to which a "knowing when" and a "knowing why" have certainly to be added) could be a useful guideline for our understanding of the functional evolution of brain structures. The Piagetian assumption that higher cognitive functions have their roots in simpler biological mechanisms still deserves consideration.

In suggesting that the first step in working out a distinction between body image and body schema is to distinguish between a conscious awareness of one's own body and a non conscious performance of the body, Gallagher (1986) points to what we have to consider as the most challenging issue that faces contemporary neuroscientists eager to find an explanation in terms of structural and functional neural supports.

3) The presence of a double dissociation between an explicit tactile detection at the level of the perceptual experience and the ability to point automatically to the site of a non-perceived tactile stimulus at an sub-conscious, implicit level. However, raises the question of the neural structures involved and then the problem of modularity. Are there separate cortical or subcortical systems subserving respectively the cognitive and the sensorimotor performances?

Many studies concerning the posterior parietal areas (Stein, 1991) have clearly demonstrated the importance of this system in sensorimotor control and space orientation processes.

In explaining the recovery of motor control in their patient with severe impairment of somæsthetic processing following a cortical lesion restricted to the primary sensory area, Brochier *et al.*, (1994) joined our earlier proposal to look at the possible involvement in the somæsthetic pathways of separate parallel streams of information-processing not dissimilar to those attributed to the visual system. In addition to the large tactile input from the dorsal column-lemniscal system via the ventro-postero-lateral nucleus of the thalamus, they hypothesise the involvement of a separate projection from the lateral posterior nucleus to the posterior parietal cortex (areas 5 and 7). This spared channel (which bypasses primary somatosensory cortex) is assumed to provide the patient with the basis for co-ordinated movements of the deafferented hand. A summary diagram of afferent somæsthetic pathways in humans published by Martin, (1985) support such an hypothesis (Figure 5). A part of the medial lemniscus fibres projecting to the posterior nuclear group of the thalamus reach directly the posterior parietal cortices.

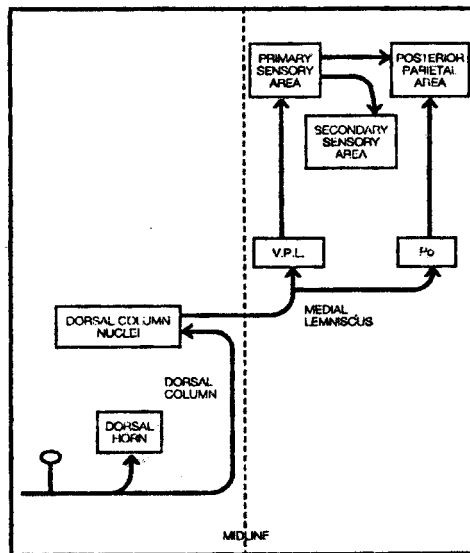


Figure 5. *Somaesthetic ascendant channels* VPL: Ventral posterior lateral nucleus of the thalamus. PO: Posterior nucleus group of the thalamus. (From Martin, 1985).

An alternative explanation (mentioned by Halligan *et al.*, 1995) has been suggested by Jeannerod *et al.* (1984) in their own study of RS (Paillard *et al.*, 1983). They suggest the sparing of somæsthetic afferents identified by Asanuma *et al.*, which project directly from the VPL thalamic nuclei to the motor cortex. While not permitting conscious awareness of detection, they might provide for RS's ability to localise stimuli on the affected limb. If the primary somæsthetic area is recognised as a requisite for the access to a conscious percept, a possible role of the secondary sensory area (*S2*) in the mediation of a covert processing of tactual information sometimes suggested remains much more controversial (Murray & Mishkin, 1984).

A recent publication (Levy & Goldman-Rakic, 1999) supports a functional

segregation within the dorsolateral prefrontal cortex: the dorsolateral prefrontal cortex (area 46/8A). The latter is selectively involved in spatial working memory, whereas the dorsomedial convexity (area 9/8B) is not critically engaged. This region that is massively afferented by somæsthetic information coming from area 5 could be a possible candidate for mediating the intended spatially oriented behaviour.

As first observed by Moll and Kuypers (1977), in rhesus monkeys trained to reach to a visible food reward from behind a transparent screen, extended lesions of the premotor cortex, including the supplementary motor area cortex and the dorsomedial premotor cortex, caused the monkeys to be unable (when using the arm contralateral to the lesion) to make the detour around the obstacle to obtain the food. Interestingly, however, the animals persevered in projecting their arms straight toward the visible reward while repetitively bumping the screen. The authors suggested that this behaviour might reflect a disinhibition of the brainstem pathways that steers the arm and hand straight to a visual target in the same way as the superior colliculus, for example, may trigger an oculomotor saccade.

The involvement of the brainstem structures in automatic painting under the control of the colliculus is worth considering. The collicular structures (the former optic tectum) which receive projection from the main sources of exteroceptive information with multiple sensory representation (including separate visual, auditory and somatotopic maps) are considered as the main organisator of spatially oriented movement of the body as a whole and of its mobile segments (review in Paillard, 1990; Stein & Meredith, 1993). Eye/head coordination and eye/hand coordination for instance are entirely controlled via the colliculus in conjunction with the cerebellum and associated brain stem networks involved in the associated postural adjustment. Interestingly, eye and hand movements involved in the blind sight performance after surgical deafferentation of the primary visual areas are mediated through collicular information projecting in the posterior parietal cortex via the pulvinar.

This subcortical contribution to the implicit sensorimotor control of goal directed behaviour seems to be excessively underestimated in the contemporary literature of motor control and in the most recently proposed functional models of the internal body representation which still show a persistent confusion between body schema and body image.

4) Although the history of the concept is richly documented (see for instance Vallar, 1999) we will restrain our conclusion to a short overview of four models most recently published.

4.1 According to Melzack (1990) corporeal awareness relies upon a large neural network where somatosensory cortex, posterior parietal lobe and insular cortex play crucial and different roles, as indicated by the effects of selective lesions in this network. His model is largely inspired by the new excitement generated by the performance of simulated neural network. In his view, the body schema, considered as a unified concept, should be subserved by a distributed neural network or neuromatrix, largely prewired by genetics but open to continuous shaping influences of experience, which includes the somatosensory system,

reticular afferents to the limbic system, and cortical regions that are important to self-recognition and recognition of external objects and entities. Phantom phenomena would be caused primarily by the persisting activity of neuromatrix components that have been deprived of their normal inputs because of the loss of a body part, and by the brain's interpretation of this activity as originating from the lost part. The field of validation of the model covers mostly if not exclusively the neurological disorders associated with the higher cognitive processing of the perceived and memorised representation of a body image without considering the potential role of implicit low level sensorimotor processes.

4.2 The most elaborated connectionist model proposed in this field is probably that of Morasso & Sanguinetti, (1995) In a line similar to that prevailing in the Melzack model, also based on a unified concept of body schema Morasso views the body schema as an internal model, necessary for the initiation and planning of goal-oriented movements. It is not for him a mere association of kinæsthetic and somæsthetic clues but rather a framework where multimodal clues are integrated. Following Stein (1991) he considers the Posterior Parietal Cortex as the most likely site for this kind of body representation incorporated in a complex network including the motor and premotor areas and the other part of the posterior parietal cortex as well as sub-cortical and spinal circuits. Within this framework, Morasso aims at the development of a computational body schema, responsible for motor planning, trainable via self-teaching and organised as a computational map (Knudsen *et al.*, 1987) but capable to incorporate time task constraints and regularisation criteria. The model, called the *Self Organizing Body Schema* (SO-BOS), is based on the introduction of computational rules derived from previous work from this group on relaxation dynamics in motor control and is theoretically able to simulate the most sophisticated adaptive properties necessary required for co-ordinating the flexible complex muscular synergies involved in the organisation of goal oriented behavioural activities.

4.3 Among the recurrent problems traditionally tied to the question of body awareness is that of the emergence of the self-awareness ("image de soi", Lhermitte, 1942). Bud Craig (1994) recently argues that the phylogenetic evolution of the cortical lamina 1 - VMpo - * interior insula pathway suggests that this integrative system embedding, among others, processes responsible for the specific sensations of pain and temperature (that are preserved in our peripherally deafferented patient) is most highly developed in human beings. This network in humans is presumed to engender the sense of the condition of the body, or the "feelings" from the body that provide the underpinning for basic emotional and motivational states. This insight gains fundamental significance from the neurological concept that insular cortex is integral for the mental generation of the image of the self that underlies the basic emotional states required for the motivation to make rational decisions affecting survival and quality of life (Damasio, 1993).

4.4 At last we will briefly comment a comprehensive review just published by Berlucchi and Aglioti (1997) devoted to the problem of the neural bases of corporeal awareness.

Since the beginning the authors show off clearly what they aim to study: "the mental construct that comprises the sense impressions, perceptions and, ideas about the dynamic organisation of one's own body and its relations to that of other bodies, is variously termed body schema, body image and corporeal awareness". Accordingly, the paper offers an interesting survey of the current studies concerning the putative brain mechanisms that underlie the "mental representation" of the body mainly stressing the dynamic aspects of this representation and emphasising the putative role and meaning of stability and plasticity in sensory cortical maps. They specially stressed the unique documentation provided by human amputees for establishing the permanent commitment of specific brain regions to conscious representation of specific body parts.

4.5 Finally, we would like to close this survey to mention studies which, in contrast with the above described models take into consideration "the perceptual and automatic aspects of the postural body scheme" (Gurfinkel & Levick, 1991), or "the pragmatic and semantic processing modes of kinæsthetic information" (Rossetti *et al.*, 1995), without forgetting the welcome terminological and conceptual clarification made by Gallagher in the field of body awareness (Gallagher & Cole, 1995). Such a functional dissociation is expected to provide a productive ground for a better understanding of how the cognitive brain can cohabit and cooperate with its basic sensorimotor machinery (Paillard, 1987).

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