Disorders of Body Representation
Corps et cognition: l'embodiment

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Theory of Pain Laboratory

The Body is something we own
Information about one’s body is crucial for one’s interaction in the world, in the same way in which the puppeteer cannot efficiently move a puppet without knowing how this is made.

The Body is something we see
The body is a highly-familiar stimulus that it is seen in everyday contact with other members of one’s family, friends, colleagues, etc.
A neuropsychological approach?

Neuropsychological methods and observations have significantly contributed to our knowledge of several cognitive faculties.

Most of these faculties (language, visual processing, imitation, etc.) are the object of complex theories.

Is the same about body representation?

A neuropsychological approach?

Neuropsychology (and possibly all cognitive sciences) has only recently addressed theoretically few early anecdotal observations.

• Disorders of body representations are rare, and often undetected in the clinical context
• Sometimes were dismissed as psychiatric symptoms


A neuropsychological approach?

First observations of disturbes of body knowledge:

• Anecdotal observations of specific symptoms (plus some experiment with little theoretical justification)
• Associate these deficits to a vague (but popular) concept of Body Schema
• Subsequently, some of the same symptoms were used to prove the validity of this concept

Summary

Disorders of Body Representation

- (pre)Historic perspective
- Patients suffering from deafferentation
- Phantom Limbs and related phenomena
- Autotopagnosia

The Homunculi

Montreal procedure → an approach for eliminating epileptic seizures.

Epileptic patients were subjected to brain surgery awake (with local anesthesia).

Patients described their sensations, when different parts of the brain were stimulated.

Wilder Penfield (1891–1976)

In 1937 he investigated «the order and the comparative extent» of the sensorimotor strip.

How to represent topographically the effects of stimulations?

He asked an artist to draw a «visual image of the size and the sequence of the visual areas»

First sensorimotor homunculus!

This conceptual leap was replicated in 1950 with differentiations between hemispheres, but also between somatosensory & motor responses.

*The Homunculi*


Given the popularity of the approach, the homunculi multiplied in Penfield’s work. In 1954, he also described:

- an homunculus in the parietal operculum (secondary somatosensory cortex)
- an homunculus in the supplementary motor area
- an homunculus in the ventral-posterior thalamic nuclei

*The Homunculi*

The notion of homunculus has been extremely popular but also criticized.

Electrical studies on animals suggest that simple somatotopic organizations might be oversimplistic.

In monkeys, only in the sensorimotor strip, there are several maps, each with different properties.


Modern investigations of somatotopic representations in humans with neuroimaging techniques.


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Eickhoff, SB et al. (2007). Cerebral Cortex.
Modern investigations of somatotopic representations in humans with neuroimaging techniques

Eickhoff, SB et al. (2007). Cerebral Cortex

The Homunculi
At the end of the XIX century, the awareness of the body was referred as *cenesthesia*, which was the sum of sensory impressions from viscera, muscle, skin, etc.

*Hermann Munk* (1839–1912) was one of the first to theorize a high-level organization of body awareness in the parietal lobe.

Experiments on cortical extirpation in dogs (1890)

The parietal cortex is the site where the body orientation is computed and maintained (even if sensory inputs change)

The parietal cortex compares sensations with «images» of previous sensations

Somatotopic organization: the parietal cortex is divided in many sub-areas, one of each body part

Small lesions can result in selective loss of «images» of specific parts.

Big lesions can result in the loss of the whole body «image»
Body Consciousness or Somatopsyche

Different external (visual, tactile, auditory) and internal inputs (muscular, visceral) gave rise to “images” of different body parts that were stored in memory.

He applied these concepts to the study of psychoses.

Carl Wernicke (1848–1905)

A supra-ordinal Homunculus?

Body representational disorder

Historical cases of disordered body representation:

“I do not feel my limbs any more. I do not feel my head. I have to touch myself incessantly to know how I am […] I am not how I was any longer. I cannot find myself again, I try to think and I cannot represent myself”.

No other neurological disorders nor delusions were present, and intelligence was preserved.

Foerster O. (1903). Monatsschrift für Psychiatrie und Neurologie

Dany G. & Camus P. (1905). Revue Neurologique

Disorder of the Body Schema

Brain damaged patients with vestibular impairments (1905).

These patients reported their body parts as being absent, smaller, bigger or misallocated with respect to their actual positions.

hyper- or hyposchématie: patients with the illusory over- or underestimation of the size of the whole body.

Pierre Bonnier (1861 – 1918)

Disorder of the Body Schema

Brain damaged patients with vestibular impairments (1905).

These patients reported their body parts as being absent, smaller, bigger or misallocated with respect to their actual positions.

**paraschématie**: patients with the illusory perception of some body parts as drifted from their original position.

Disorder of the Body Schema

Brain damaged patients with vestibular impairments (1905).

These patients reported their body parts as being absent, smaller, bigger or misallocated with respect to their actual positions.

**aschématie**: patients showing a strong inability to localize the boundaries or the postures of their own body.

Disorder of the Body Schema

Distinction between:

- **Sensorial image** → peripheral sensation (sound, light, temperature, consistency, etc.)
- Definition of the locus of the perceived point (regardless of the input channel) → supra-ordinal representation

**Pierre Bonnier** (1861 – 1918)

Disorder of the Body Schema

• Introduction of term schema → to denote a representation of the body with a spatial main feature

• Description of several disorders of the body schema (aschématie, paraschématie, etc.)

• Associated these deficits to a vestibular syndrome, following damage to the medulla oblongata

Disorder of the Body Schema

One patient unable to report the position of his own hand while still being able to localize the position of a perceived tactile spot

Postural Schema: representation of the position and movement of the body, derived by the integration of multiple sensory channels (proprioceptive, vestibular, etc.)
One patient unable to report the position of his own hand while still being able to localize the position of a perceived tactile spot

*Superficial Schema*: representation of spatial locations over the body surface.

**Disorder of the Body Schema**

Description of several deficits related to the Body Schema

- 1908. Inability to point to (one’s) body parts at command: Autotopagnosia
- 1915. Phantom Limb phenomena
- 1922. Inability to appreciate the position of body parts.

**Disorder of the Body Schema**

Multiple *schemata*, associated with different sensory modalities and body parts.

The conscious awareness of the body originates from these schemata.

In children, corporeal awareness is mainly tactile and kinesthetic.

In adults, corporeal awareness is also heavily visual.
Disorder of the Body Schema

Paul Schilder (1886 – 1940)
Jean Lhermitte (1877 – 1959)
Josef Gerstmann (1887 – 1961)

Summary

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- (pre)Historic perspective
- Patients suffering from deafferentation
- Phantom Limbs and related phenomena
- Autotopagnosia

Proprioceptive deafferentation

Can sensory peripheral pathologies tell us something about how the brain processes the body?

Proprioceptive deafferentation: loss of all (non-visual) input that informs about the position of the body in space
• CNS receives proprioception information from sensory neural pathways that begin in specialized sensory neurons known as proprioceptors
  – Located in muscles, tendons, ligaments, and joints
• Three primary types of proprioceptors
  – Muscle spindles
  – Golgi tendon organs
  – Joint receptors

Proprioceptive deafferentation

1. Muscle spindles
• Mechanoreceptors that detect changes in muscle fiber length (i.e. stretch) and velocity (i.e. speed of stretch)
• Function as a feedback mechanism to CNS to maintain intended limb movement position, direction, and velocity
• They are innervated by large, myelinated primary afferent fibres (Aα)

Proprioceptive deafferentation

2. Golgi-Tendon Organs
• In skeletal muscle near insertion of tendon
• Detect changes in muscle tension (i.e. force)
• Subserved by large, myelinated fibers (Ib, Aα)

Proprioceptive deafferentation

3. Joint Receptors
• Several types located in joint capsule and ligaments
• Mechanoreceptors that detect changes in force and rotation applied to the joint.
• Innervated by small afferent fibers
### Proprioceptive deafferentation

<table>
<thead>
<tr>
<th>Patient IW</th>
<th>Patient GL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuronopathy due to autoimmune response to viral infection at 19 years.</td>
<td>Neuronopathy due to autoimmune response to viral infection at 17 years.</td>
</tr>
<tr>
<td>Loss of large myelinated sensory fibers below the neck.</td>
<td>Loss of large myelinated sensory fibers below the mouth.</td>
</tr>
<tr>
<td>Perception of pain and temperature intact</td>
<td>Perception of pain and temperature intact</td>
</tr>
</tbody>
</table>


### Proprioceptive deafferentation

Three primary types of proprioceptors

- **X** Muscle spindles → large myelinated fibers
- **X** Golgi tendon organs → large myelinated fibers
- √ Joint receptors → small fibers

Some residual tactile processing: in a two-alternative forced choice situation and reported that the sensation, though weak, had a pleasant character.

Proprioceptive deafferentation

In GL insula activity shows enhanced connectivity with the visual cortex, as reorganization of spared tactile sensitivity with visual information.


Proprioceptive deafferentation

Although both patients had spared motor fibers, they were associated with heavy deficits in motor control and coordination.

Movement was no longer automatic, but relied on visual feedback, concentration and intellectual effort.

They had to sleep with the light on to know their position during the awakening.


Proprioceptive deafferentation

Although both patients had spared motor fibers, they were associated with heavy deficits in motor control and coordination.

IW re-learned to walk, but he needed to concentrate to move each foot.

If he sneezed, he lost concentration and fell over.

Although both patients had spared motor fibers, they were associated with heavy deficits in motor control and coordination.

**Proprioceptive deafferentation**

If vision of their own hand is occluded, the could not adapt the aperture of their fingers to match the size of the to-be-grasped object.


Patient GL (plus 7 controls not-deafferentated) were asked to imagine to join the tips of the thumb and of the little finger.


**Proprioceptive deafferentation**

A dynamic state during which an individual mentally simulates a given action. The subject feels himself/herself doing the action, even though no real movement occurs.

Imagined and real movement share similar proprieties: temporal regularities, biomechanical constraints, brain activity.

Roth M. & Decety J. (1996). NeuroReport
Patient GL (plus 7 controls not-deafferentated) were asked to imagine to join the tips of the thumb and of the little finger.


A pulse of current flowing through a coil of wire generates a magnetic field. If its magnitude changes with time, then it will induce a secondary current in any nearby conductor (THE BRAIN).

TMS effect
Muscle pre-activation

Transcranial Magnetical Stimulation (TMS)

Proprioceptive deafferentation

Mercier C. et al (2008), Cerebral Cortex
Proprioceptive deafferentation

In controls, proprioceptive information plays a role in the program and imagined execution of actions.

If current posture is incompatible with the intended action, motor imagery is impaired


Proprioceptive deafferentation

In GL, where no proprioceptive input is present, the effect is visible only when information about current posture is available from the eyes.

Motor programming without proprioceptive info


Proprioceptive deafferentation

**One’s Action Recognition**

Subject moves a joystick. The hand is hidden from sight, but a virtual hand is instead displayed on a monitor.

The virtual hands moves as the subjects', with angular biases.

One’s Action Recognition

“Did the movement you saw on the screen exactly correspond to that you have made with your hand?”

Proprioceptive deafferentation


Subject moves. The hand is hidden from sight.

A cursor on a computer screen moved either synchronously or asynchronously with the finger.

Proprioceptive deafferentation


IW is less proficient than 6 age-matched controls in identifying whether the movement of the stimulus was synchronous/asynchronous with his own.
Others’ Action Recognition

Participants saw videos of individuals lifting heavy vs. light objects.

Sometimes the people in the video were deceived on the real object weight (it is heavier than it looks).

Proprioceptive deafferentation


IW and GL show comparable performance than 12 controls in estimating the weight of the object.

They show poorer performance than 12 controls in estimating whether the person in the video was deceived or not.

Proprioceptive deafferentation

Motor Tasks
- Impaired coordination (especially without vision)

Non-Motor Tasks
- Impaired motor programming (strong reliance on vision also during imagined movements)
- Impaired recognition of one’s own movements
- Impaired inference of others’ states from their movements
Thermal stimuli (which they could still feel) were delivered to different parts of their body, while this was hidden from sight. They could describe verbally the anatomical location where the thermal touch occurred, but they could not point it with their arms.


Patient RS
Parietal Lesion following obstruction of the left posterior parietal artery, occurred during brain surgery.

Hemianopia, hemianacousia, hemianaesthesia


Patient RS
Parietal Lesion following obstruction of the left posterior parietal artery, occurred during brain surgery.

Hemianopia, hemianacousia, hemianaesthesia (especially in the distal parts of her body)

RS was unable to report verbally any tactile, thermal or painful event to their arms and legs. However she could point (with the left arm) precisely to the location of her body in which the stimulation occurred.

“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?”

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<table>
<thead>
<tr>
<th>Deafferentation</th>
<th>IW</th>
<th>GL</th>
<th>RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal description of the touched part</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Pointing to the touched part</td>
<td>X</td>
<td>X</td>
<td>✓</td>
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</table>
Two-way body system

The “Body” is:

1. An egocentric reference frame for directing our actions in the external space (but also for locating skin sites at hand’s reach → Body Schema)

2. An object situated in the external space with invariant properties → Body Image


Summary

Disorders of Body Representation

✓ (pre)Historic perspective
✓ Patients suffering from deafferentation
   ➢ Phantom Limbs and related phenomena
   ➢ Autotopagnosia

Phantom Limbs

Amputees and individuals who are born without a limb, often continue to feel the presence of their missing limb and report that the phantom limb has certain sensory properties like touch and pain.

After Lord Nelson lost his arm during an unsuccessful attack, he experienced compelling phantom limb sensations (pain). He claimed that this was “direct proof of the existence of the soul” …direct proof that the human brain holds a representation of the human body, and that this representation sometimes diverges from the individual’s real body.
Phantom Limbs

- After amputation still feels like limb is there, attached to body, moving appropriately with other body parts.
- Can also happen when born without a limb or when the limb is present but paralyzed.
- Constant pain for some.
- Not all phantom limb experience is painful.
  - Feel gesturing, itches, twitch or even attempts to pick things up.
- Phantom arms will swing while the person walks.
- Phantom fingers will grasp for a cup as a man aims his stump toward the table.
- A man reported falling out of bed in the morning when he tried to bear weight on his phantom leg.
- Sensation of a watch or ring can often be felt.
- Phantom arms will swing while the person walks.
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Phantom Limbs

- Not only limbs; also breasts, male genitalia, face parts (jaw), etc.
- Phantom sensations can be evoked in amputees, by appropriate sensory stimulations.
- Not-only-somoesthetic: visual, auditory and olfactory phantom sensation might follow de-afferentation of corresponding sensory organs.
- Amputated limbs can sometimes be seen, other than felt.
- Phantom limb also without limb loss (e.g., feeling a third arm): supernumerary body part.
- Time-dependent: stronger after amputation, might decrease over time.
  - Telescoping: gradually retracts towards the stump.
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Phantom Limbs

- If the patient gets visual feedback that the phantom is obeying the brain’s commands, symptoms might be weakened.
- Mirror imaging of limbs using a mirror box:
  “Look into side of the mirror so that you see the reflection of your intact hand superimposed on the felt location of your phantom hand.”
  “Then try to make symmetrical motions using both hands (e.g., conducting an orchestra).”

Peripheral Hypothesis

- Following a nerve cut, formation of neuromas are seen, which show spontaneous and abnormal evoked activity following mechanical and chemical stimulation. (Amir, et al 1993)

Reorganization Hypothesis

- One study of adult monkeys revealed cortical reorganization in which the mouth and chin invade cortices corresponding to arm and digits. (Dotrovsky, et al 1999)
- In humans, similar reorganization has been observed using magnetoencephalographic techniques and there was a linear relationship between pain and degree of reorganization (Flor, et al 1998)
Cortical reorganization correlates with the pain felt in the phantom limb.
Phantom limb sensations are due to the "cross-wiring" of the somatosensory cortex.

Ramachandran (1993;2000)

Critiques
Congenital Phantoms

How can peripheral and reorganization hypotheses account for congenital phantoms?

Weinstein et al. (1962) described 13 aplastic individuals with phantom sensations
• 7 could imagine moving the missing limb
• 3 exhibited telescoping effects.

Ramachandran (1993) described a woman born without arms, who had phantom sensations of her arms «gesticulating» during conversation.

How can peripheral and reorganization hypotheses account for congenital phantoms?

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It is however possible, that patients develop phantoms of missing limbs from the observation of equivalent parts of others full-bodied individuals.

**Critiques**

**Congenital Phantoms**

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**Critiques**

**Parietal Dysfunction**

Phantoms do disappear much more frequently after cerebral lesion, than after peripheral treatment:
- the parietal cortex controlateral to the missing part
- not controlateral primary somatosensory cortex (which is the one primarily reorganized)

Phantom sensations are not only tactile and painful, but involve also movements, changes of postures, etc.

**Transcranial direct current stimulation (tDCS)**

- Electrical stimulation ~ 1-2mA
- Does not cause resting neurons to fire (Purpura and McMurtry, 1965; Terzuolo and Bullock, 1956).
- Believed to modulate the firing rate of active neurons.
- Depending on polarity, tDCS can induce cortical excitability reduction or enhancement can persists for hours.
Anodal stimulation of M1 reduces temporary phantom pain, but not phantom sensations.

Bolognini N et al. (2013). PAIN

Cathodal stimulation of PPC reduces temporary phantom sensations, but not phantom pain.

Bolognini N et al. (2013). PAIN

Phantom sensations and phantom pain are double dissociable.

Phantom sensations can be caused by a hyper-exhitation of PPC, which cathodal tDCS can counteract.
“…a network of neurons that, in addition to responding to sensory stimulation, continuously generates a characteristic pattern of impulses indicating that the body is intact and unequivocally one’s own”

“in the absence of sensory inputs from the body, it would create the impression of having a limb even when the limb has been removed”

The NeuroMatrix would be genetically pre-wired


**NeuroMatrix**

a) thalamus $\rightarrow$ somatosensory cortex (sensory pathway)

b) brain stem $\rightarrow$ limbic system (important for emotion & motivation)

c) parietal lobe and connected regions (important for Self recognition and evaluation of sensory signals)

Sensory input $\rightarrow$ Perception of body part within unitary Self


**NeuroMatrix**

«cerebral neurons that once responded to the lost or paralyzed limb develop strong connection with still sensate parts of the body, and then begin to serve those regions»

Although genetically pre-wired, the NeuroMatrix can be reorganized

Sensory input $\rightarrow$ Perception of body part within unitary Self

**Winner-take-all scheme**

a) Peripheral effects (stump neuromas)  
b) Cerebral reorganization  
c) Motor commands & corollary discharge  
d) Internal image of one’s own body  
e) Somatic memories of the original limbs

These five sources of information reinforce each other when consistent, whereas isolated discrepancies are disregarded for coherence sake.


**Winner-take-all scheme**

a) Peripheral effects (stump neuromas)  
b) Cerebral reorganization  
c) Motor commands & corollary discharge  
d) Internal image of one’s own body  
e) Somatic memories of the original limbs

But when the discrepancies are more than isolated cases, this might lead to particular symptoms such as somatic, painful or motor phantoms.


**Phantom Limb & Body Schema**

NeuroMatrix (or winner-take-all scheme) = Body Schema?

1) Convergence of multisensory information  
2) Codes information which are integrated in one’s motor plans  
3) Partially implicit  
4) Relies strongly (but not exclusively) on the parietal cortex

Most of these features are typical of the Body Schema as identified by the study of other kinds of patients.
Mental Rotation

“Are the Two pictures one the mirror-image of the other?”


Mental Rotation

“Are the Two pictures one the mirror-image of the other?”

Handedness Task

Is this hand right or left?
Mental Rotation of hand stimuli: participants have to assess the laterality of an oblique hand (Parsons, 1987). Response Times increase as a function of:

• the angular distance between the stimulus and participants’ hand.
• whether or not such distance describes a possible movement.

Handedness Task

Medial Over Lateral Advantage (MOLA) or awkwardness effect

Neural correlates: performances in such task has been associated with increased neural activity in sensori-motor structures:

• Premotor cortex
• Supplementary motor area
• Cerebellum
• etc.

**Handedness Task**

- **Egocentric extrinsic coding**: the position of one’s hand in the external environment, including its distance from the hand-stimulus.
- **Action Representation**: programming and (imagined) execution of one’s hand movements towards the displayed stimulus:
  - **Biomechanical constraints**: degrees of freedom for obtaining the desired movement.
  - **Inverse model**: which sequence of muscle contractions will produce the expected movement?
- **Matching** one’s hand with the displayed stimulus.
- **Egocentric intrinsic coding**: If the matching is positive: did I moved my right or left hand?

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**Handedness Task**

It is a specific kind of motor imagery task, in which the programming and the (imagined) execution of a specific movement is spontaneously triggered by the task demands (i.e., evaluation of the laterality of a hand).

“It is now well documented that motor imagery shares many properties with physical actions at the physiological level (muscle activity), at the kinematic level (similar physical constraints and laws) and at the neural level (shared patterns of brain activation). As such, motor imagery constitutes a good task to assess the integrity of the body schema.”

De Vignemont, F (2010). Body schema and body image. Neuropsychologia
Do individuals with phantom limbs exhibit impairments in tasks tapping the Body Schema (e.g., handedness task)?

In particular:

What is the behaviour of patients congenitally born without one (or more) limbs might feel phantom sensation of that body part that they never owned?

Patient AZ, affected by tetra-amelia (congenital absence of all four limbs) exhibited phantom sensation as long as she could remember.

The patient was engaged in the handedness task, and exhibited a spared MOLA effect, proving that she was biased by biomechanical constraints of limbs she never owned.
This motor imagery task was associated with increased activity in the motor cortex.

Nico et al. (2004) conducted a group study on 19 patients with one limb missing:

- 16 were amputees with phantom sensation of the missing limb
- 3 had congenital absence of a limb, but never exhibited phantom sensation

All patients were engaged in a handedness task:

Assessing the laterality of a hand is more difficult when the homologous portion of the body is missing. Nevertheless, information about the biomechanical constraints of the amputated limb is retained (MOLA).
Nico et al. (2004) conducted a group study on 19 patients with one limb missing:

• 16 were amputees with phantom sensation of the missing limb
• 3 had congenital absence of a limb, but never exhibited phantom sensation

All patients were engaged in a handedness task:

Wearing an aesthetic prosthesis severely impaired the ability of evaluate the laterality of a stimulus of homologous side

The information about the biomechanical constraints of the never-owned limb is missing (no MOLA) ≠ AZ (Brugger et al., 2000) which had phantom sensations.
Funk & Brugger (2008) conducted a group study on 14 patients with congenital absence of limbs:

- 14 absence of one arm, and no phantom sensations
- 1 congenital absence of all limbs and phantoms (patient AZ)
- 1 congenital absence of both arms and no phantoms (CL).

All patients were engaged in a handedness task:

**Phantom Limb & Body Schema**

1. Amputation impairs, but does not prevent, the engagement of the Body Schema in the handedness task.

2. Congenital absence of one limb (no phantoms) lead to mixed results: one study report faulty use of the Body Schema in the task (Nico et al., 2004), whereas another study suggest that (despite some difficulties) a representation of the limb that it is never owned (Funk & Brugger, 2008)

Can a representation of the missing limb be based on the information from the controlateral limb?

3. Congenital absence of both limbs provides different results on the basis of whether patients feel exhibit phantom sensations of the body parts that they never owned

   - Patient AZ (who has phantom sensations of the missing limbs) shows spared ability to engage the Body Schema in the handedness task
   - Patient CL (who never experienced phantom sensations) was unbiased by the biomechanical constraints of those limbs he never owned.

Apparent-motion task

The performance of patients AZ and CL in both handedness and apparent motion tasks converges. AZ not only reported phantom sensations of the limbs she never owned, but also her performance in both tasks suggest that these limbs are part of her Body Schema. CL never reported phantom sensations, and his performance in both tasks suggest that these limbs are not part of his Body Schema.

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✓ Autotopagnosia

Autotopagnosia

αὐτο- τόπος ἀγνωσία
(self space unawareness)

Patients with an inability to locate body parts (e.g. through pointing tasks).

The discovery of the syndrome has been attributed to Arnold Pick, although very little details are present about patients’ symptoms.

Patients with left parieto-temporal damage may exhibit Autotopagnosia (e.g., Sirigu et al., 1991), that is the inability to locate (point to) parts of a human body, regardless of whether this is:

- One’s own
- The experimenter’s
- A drawing or a mannequin

Patients with left parieto-temporal damage may exhibit Autotopagnosia (e.g., Sirigu et al., 1991), that is the inability to locate (point to) parts of a human body, despite being still able to identify those parts that they cannot locate.

“This is a knee. It is useful to bend my leg.”


Patients with left parieto-temporal damage may exhibit Autotopagnosia (e.g., Sirigu et al., 1991), that is the inability to locate (point to) parts of a human body, despite being still able to locate parts of other objects.

Patients with left parieto-temporal damage may exhibit Autotopagnosia (e.g., Sirigu et al., 1991), that is the inability to locate (point to) parts of a human body, despite being still able to make the exact same movements necessary for pointing for a different target.

<table>
<thead>
<tr>
<th>Autotopagnosia</th>
<th>Spatial location of body parts</th>
<th>√</th>
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<tbody>
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<td>Spatial location of objects parts</td>
<td>√</td>
</tr>
<tr>
<td>AUTOTOPAGNOSIA</td>
<td>Identification of isolated body parts</td>
<td>√</td>
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<tr>
<td>AUTOTOPAGNOSIA</td>
<td>Programming (pointing) movements</td>
<td>√</td>
</tr>
</tbody>
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Not a deficit of the Body Schema
(Patients can point ≠ deafferentation cases from Paillard)

Not a deficit of Body Image
(Patients have intact conscious representation of the body)

• **Body Schema**: representation of one’s own posture at each moment (built by integrating of information arising from different sensory modalities).

• **Body Image (or Body Semantics)**: explicit knowledge about the human body.

• **Body Structural Description (or Body Configural representation)**: representation of the configuration of a “standard” body.

(Sirigu et al., 1991; Buxbaum & Coslett, 2001; Schwoebel & Coslett, 2005)
Structural Description models (e.g., Biederman, 1987; Marr & Nishihara, 1978) → the representation of object is based on (1) the identification of its constituent parts, and on (2) the information about how these parts relate one another.

Objects are virtually infinite.

How can my brain process them all?
It has been suggested that Autotopagnosia may reflect a trouble in coding the spatial relations among body parts, leaving a spared ability in identifying them (Sirigu et al., 1991; Buxbaum & Coslett, 2001; Schwoebel & Coslett, 2005).

Multiple Body Representations

Schwoebel & Coslett (2005) tested 70 stroke patients and found a three-way dissociation.

- 13 patients exhibited impaired performance only in a motor imagery/handedness task (Body Schema)

Multiple Body Representations

Schwoebel & Coslett (2005) tested 70 stroke patients and found a three-way dissociation.

- 3 patients exhibited impaired performance only in the task testing the Body Semantics.
Schwoebel & Coslett (2005) tested 70 stroke patients and found a three-way dissociation.

- 2 patients exhibited impaired performance only in tasks testing the Body Structural Description (left temporal and parietal cortex).

**Multiple Body Representations**

- Which anatomically closest?

**Autotopagnosia vs. Heterotopagnosia**

- Superior Parietal damage: inability to locate only parts of their own body (autotopagnosia)
- Inferior Parietal damage: inability to locate only parts of others' body (heterotopagnosia)

(Felician et al., 2003; Cleret de Langavant et al., 2009; Auclair et al., 2009)

**Pointing to one's own body**

Felician et al. (2004) asked healthy participants to point to parts of their own body (as opposed to parts of the scanner), and found activations of the intraparietal sulcus and of the superior parietal cortex.
Felician et al. (2009) asked healthy participants to point to parts of someone’s else body (as opposed to parts of a dog), and found activations of the left angular gyrus, the precuneus and medial prefrontal cortex.

Pointing to others’ body

Multiple Body Representations

- **Body Schema**: representation of one’s own posture at each moment arising from different sensory modalities.
- **Body Image (or Body Semantics)**: explicit knowledge about the human body.
- **Body Structural Description (or Body Configural representation)**: representation of the configuration of a “standard” body.

It has been suggested that Autotopagnosia may reflect a trouble in coding the spatial relations among body parts, leaving a spared ability in identifying them (Sirigu et al., 1991; Buxbaum & Coslett, 2001; Schwoebel & Coslett, 2005).

Body Structural Description

How the body is usually like

Heterotopagnosia

Representation of parts

Representation of how the parts relate one another in the full body
Clinical definition: Apraxia refers to a deficit of the motor activity that emerges specifically during the execution of intentional actions.

It is not due to:
- deafness, or aphasia
- primary sensory weakness (blindness, anesthesia) or agnosia
- paresis, tremor, ataxia
- ipokinesia or iperkinesia
- impaired spatial orientation
- frontal inertia or dementia

1900: single case report of a left handed patient afflicted by syphilis who had apraxia when he performed an imitation task with the left but not the right hand.

1905: 20 (of 41) patients with right hemiplegia had also apraxia, 0 (of 42) patients with left hemiplegia had apraxia. The left hemisphere was specialized for motor control.

Classification according to the body part affected
- Bucco-facial apraxia (whistling, kissing, etc.)
- Trunk apraxia (movements executed with axial muscles)
- Limb apraxia (contralateral to lesion)

Functional Classification (from Liepmann)
- Ideational Apraxia (Context \ Action Schema)
- Ideomotor Apraxia (Action Schema \ Motor Command)
Apraxia

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Apraxia

Functional Classification
(from Liepmann)

• Ideational Apraxia
  (Context → Action Schema)

• Ideomotor Apraxia
  (Action Schema → Motor Command)

Ideomotor Apraxia

The inability to execute learned purposeful movements, despite having the desire and the physical capacity to perform them.

Inability of programming one’s body to execute an aimed movement, through command or imitation. BUT sometimes also inability to imitate a meaningless (random) movement.

Ideomotor Apraxia

Inability to reproduce the same movements on a manikin (although motor acts for manipulating a manikin are different from those necessary for imitating the same gesture)


Imitation of meaningless movements requires the ability of:

• inspecting the spatial relations between parts of others’ body
• convert them in corresponding relations on oneself or on a manikin.


“body part coding is interpolated between perception and production of gestures”

“it decomposes the gestures into a limited number of body parts”

“it applies independently of whether the gestures is perceived or executed and independently of the different perspectives and modalities of perceiving one’s own and other bodies (including those of a manikin)“

55 left brain damaged patients were tested in the imitation of meaningful & meaningless movements. Patients also performed a handedness task, aimed at assessing putative impairments at the Body Schema. Impairments at the handedness task correlated with imitation of both gestures.
55 left brain damaged patients were tested in the imitation of meaningful & meaningless movements.

Patients also performed a task aimed at assessing putative impairments at the Body Semantics.

Impairments at the Body Semantics correlated with imitation of meaningful gestures only.

Impairments at the Body Structural Description did not correlate with any imitation deficit.
44 left brain damaged patients were tested in the imitation of meaningless movements of hands and fingers

“Lesions of the posterior portion of the left IPL are a regular finding in patients suffering from autotopagnosia (i.e., the inability to locate body parts either on their own or on other person’s bodies)”
Ideomotor Apraxia

A disorder of Body Representation?

• Reproduce a seen body part configuration through a sequence of movements → Body Schema
• Access to the function of specific body parts in relation to the imitation of meaningful gestures → Body Semantics
• Visual screening of the observed body part relationships to be imitated → Body Structural Description (weak evidence)

Summary

Disorders of Body Representation

√ (pre)Historic perspective
√ Patients suffering from deafferentation
√ Phantom Limbs and related phenomena
√ Autotopagnosia

A neuropsychological approach?

Interim conclusions

Neuropsychology provide several information about how the brain processes the body

Multiple body representations exist which discriminate between:
• Explicit vs. implicit body awareness
• Dynamic vs. invariant body features
• Isolated parts vs. spatial relationships
• Proprioceptive vs. visual information

A neuropsychological approach?

Interim conclusions

Neuropsychology provide several information about how the brain processes the body.

The left parietal cortex plays a key role in representing spatial features of a human body, both in terms of one's own posture and in terms of standard configuration of a visual body model.


Conclusions

Body representation as Segregation:

• The brain processes the body through independent representations, that can be dissociated both at the behavioral and neural level.

• These body representations might play different roles in everyday activities (e.g., imitation), and their dysfunction might underlie different kinds of errors.

Conclusions

Body representation as Integration:

• The sense of Body is not product of one brain region, but the output of the combined activity of a wide brain network, which merges together cortical and peripheral information.

• Data from different clinical population suggest a major role of the parietal cortex, although this region alone does not explain the whole extent of the observations.
CHAPTER 17

Disorders of body representation

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Introduction

A cognitive theory about the neural representation of the human body was initially developed, supporting evidence and experiments in neuroanatomy. Neur...