

The Body Schema: History, Definitions and Propositions

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Abstract: The concept of body schema has a very complex history. Proposed by Bonnier (1902) as a "sense of attitudes" and by Head and Holmes (1911) as a "postural schema", it gave rise to confused debates until the 1980s. Clarified in France by Dolto (1984) and in the Anglo-Saxon world by Gallagher (1986), it is now well defined by neuroscience, which has taken up the subject with very clever and fertile experimental paradigms. A consensus is adopted by all: the body schema is the result of a set of sensorimotor coordinations involving proprioception and the visual – in its peripheral component – and vestibular sensory systems. Vision is a support. The vestibular system, through its neurological structure, is involved at many levels. The personal peripheral space concerns the whole body and belongs to the body schema. The development of the body schema in children is also addressed. Proposals for items for future adaptation in the psychomotor assessment are proposed.

Introduction

The concept of body schema was born at the beginning of the twentieth century. Its history is therefore more than a hundred years old. However, it took nearly 80 years to stabilize its perimeter and then its definition. At the frontier of the complex links between the body and the mind and poorly differentiated from the image of the body, it was a source of great confusion. Because it does not correspond to a clearly defined bodily function (such as digestion, for example) and does not rely on central nervous system structures that are easily identifiable without modern imaging tools, it led researchers to develop a consensus. When Dolto (84) and Gallagher (86) decide, independently of each other, to confine the body schema to the neurophysiological equipment, they have released energies. However, it was not until the arrival of brain imaging technologies that the complexity of the brain substrates on which it rests was discovered and the importance of coordinating the various sensory and spatial information it involves.

The body schema is a very important concept for psychomotor therapists, first of all because of its inclusion in the 1988 competence decree, but also of course because it concerns many types of patients. It had become necessary to propose a new definition of the body schema based on the latest discoveries with the idea of developing new tools for the psychomotor assessment and refining psychomotor care. This is the purpose of this article. Let's start with the story.

1/ The history of the body schema: a difficult past

It was Bonnier (1902) who proposed the notion of the "sense of attitudes". The state of scientific knowledge at the beginning of the twentieth century did not allow him to differentiate between attitudes and postures. If we wanted to follow in Bonnier's footsteps, we would today speak more of a sense of posture. Attitude corresponds, in fact, to the emotional message conveyed by posture.

- "The sense of attitudes provides us with the notion of the place of each part of ourselves and forms the basis of all orientation, whether objective as well as subjective and psychic. It has as its

object the topographical figuration of our self. I have also proposed the term schematography for the kind of images provided by this sense."

"This representation of the segmental attitude, born of the set of tactile images provided by the sensory-sensory innervation [...], has nothing in common with sensory tactility as it is ordinarily understood..." "

"We do not feel our muscles or joints, but the whole of these operations is revealed to us in an obtuse, synthetic and global form, but absolutely conscious as an image of attitude or of a variation of attitude..."

It is therefore "the faculty that we possess of knowing at all times how to orient any part of our body in relation to all the others."

"We don't perceive something without something." »

Bonnier has the immense merit of posing the problem of the representation of the movements and positions of the body, but he involves subjectivity and the psychic fact.

Henry Head, an English neurologist, was interested, with Holmes (1911), in sensory mechanisms. To the point of experimenting on himself. He mainly highlighted two forms of sensitivity, protopathic and epicritical.

"The sense of self is an active construct and human knowledge of the material universe depends on a set of complex physiological processes of which the mind is normally unconscious.

- Man is constantly building a constantly changing model of himself. Knowledge of the body and its relations to other objects depends on this constantly updated model. Head calls these models "schemata". These patterns are by nature dynamic. Each identified change presents itself to the consciousness bearing its relations with what has preceded it. These previous states are by nature in no way psychic. "

Head thus extends Bonnier's reasoning. However, he confines sensory information to a "non-psychic" aspect. Let Jeannerod (2010) comment on the beginnings of the body schema on the stage:

"Bonnier's sense of attitudes prefigured the notion of body schema, as it appeared in the neurological literature in 1911, with the paper by Head and Holmes. These authors proposed that sensory information from the surface and depth of the body during movements could be stored in the sensory cortex and constitute a store of "impressions."

"These can reach consciousness in the form of images, but most often they remain outside its field. They form organized models of ourselves that we can call "schemas."

The diagram represented a kind of standard to which changes in body posture could be compared:

"As we are perpetually changing positions, we are always in the process of constructing a postural model of ourselves in constant transformation. Each new posture or movement is registered on this plastic schema, and cortical activity relates to it each new group of sensations evoked by the new posture. This results in an immediate knowledge of the posture, as soon as this relationship is established."

Head and Holmes "actually contemplated the existence of several of these patterns depending on whether they were constructed from visual, tactile, or other information, which overlapped to form a

three-dimensional image of the body with which any new sensory impression was related before arriving at consciousness."

"Head and Holmes' body diagram can refer to the feeling we have of our own body and body space as well as the physiological mechanism that gives us this feeling."

Here we enter into confusion: is the corporeal schema in one way or another related to the psychic fact? The latter then took on the form of subjectivity. It was not until Damasio (1995) that, in neuroscience, the link was made between sensory systems and their coordinations and subjectivity. In the meantime, our authors will go to great lengths...

Wallon and Lurçat (1962)

"The body schema remains an ambiguous and floating notion, which varies with the authors.

-Our research has shown that the body schema does not necessarily coincide with the anatomical body, but that in the body schema there are relationships of various kinds in space, postural space and ambient space, and that one cannot study the body schema without involving the position of the body in space and without defining the relationship of the body with the body-mimed act and with the act on objects with the person of another, with a mannequin, and different results have been obtained, depending on whether it is a question of imitation or of verbal order.

-In the postural space there are also states of equilibrium, affective states, which do not coincide with the organs either."

Wallon and Lurçat do not unravel the skein but formalize the importance of space in the notion of body schema.

For **Wittling** (1968), addressing the question of

"The ontogeny of the body schema in man is to engage in a strange and confusing domain. Indeed, according to the authors, the term used is different and so is its content when we are fortunate enough to find it defined: Somatopsyché (Wernicke-Foerster, 1894), postural schema (Head and Holmes, 1911), notion of the own body (Wallon, 1931), self-consciousness (Wallon, 1932; Lévine, 1951; Lévine, 1958), self-image (Van Bogaert, 1934; Tournay, 1959), image of the corporeal self (Lhermitte, 1942), representation of the physical self (Burstin, 1957), body schema (Schilder, 1968; Spionek, 1961), image of the body and self-consciousness (R. Zazzo, 1962), lived body (Trillat, Ghasseguet-Smirguel, 1963), image of one's own person (Köhler, 1965), representation of the self (B. Zazzo, 1966)... »

All these references sometimes constitute the various designations of the same thing, sometimes the same name for various phenomena that Lhermitte (1939) encompassed under the general term of "the image of our body". In reality, it seems that we can already identify, through the fluidity of this notion, three levels of study: one predominantly physical, the other more psychological, the third more social.

- 1) The image of our body is first and foremost "the image of ourselves, the complex but strong feeling that is always present on the fringes of the consciousness of our physical personality..., the image of our bodily self, of our body of flesh" (Lhermitte, 1939).

- 2) The image of our body is then the "problem of identification and therefore, inevitably, of the 'I'". The ego is above all a 'psychic reality', therefore a 'psychic process' in the most classical sense of

the term " (Nacht, 1956). This level has been particularly studied by psychoanalysts, in the light of the work of Freud who, it should be noted, left no writing on this question.

- 3) Finally, the image of our body is "a way of being and thinking, the way in which young people construct the representation they have of themselves in the more or less reflective exercise of their roles" (B. Zazzo, 1966). This level, already more evolved, is later than the previous one, because it calls for introspection and language; as a result, its study can only be carried out on older subjects.

By pointing out the confusions, Wittling seeks to sweep them away. She does indeed propose a "physiological" conception of the body schema and clearly refers to the notion of body image. An image of the body as it was conceptualized in 1968, based on the proposals of Schilder (1968). The progress is notable but will not yet lead to support. Let us listen to J. de Ajuriaguerra (1974):

- "The term postural schema, body schema, self-image, somato-psyche, image of the corporeal ego, somatognosia includes notions that are often considered equivalent by the authors.

- In the notion of "body schema" in the broad sense of the term, we never know if it is a functional schema or if it applies to the feeling we have of our body, of our bodily space, or if it names the function of the physiological mechanisms that give us the feeling corresponding to the real structure of the body.

- The notion of "somatognosia" can also be used sometimes in the sense of becoming aware of the body and its parts intimately linked to the evolution of praxio-gnosis, sometimes as an awareness of the body as a lived reality – implicit knowledge. "

The debate takes a very different turn. One senses in Ajuriaguerra's quotation the quest for a refined conceptualization and the need for clarity. Soubiran and Coste (1975) remain in an in-between position that allows for the recognition of the importance of the organism's equipment and the consideration of the "self-aware" human subject.

- "It is important not to lose sight of the fact that the neurological, biochemical contribution is essential for a healthy and broad understanding of the body schema."

- "The subject's memory state, his capacity for actualization and integration would thus determine the conformity of his body schema to reality, a reality that in turn becomes the potential existence of the body"

- "The fundamental character of the body schema lies in the fact that it relates two essential spaces: that of the body itself and the surrounding objective space. Their reciprocal articulation refers to genetic, physiological and relational data.

- The difficulty of elucidating the body schema lies in its non-objectivity. The subject has an idea, an image, a representation, a self-consciousness of himself that he totally engages in each of his acts.

- The body schema thus appears to us as the quality of a motor adaptation to reality, having as its more or less conscious motivation a desire to adjust to the lived space and which is realized according to the possibilities inherent or assigned to the human being."

It is necessary to specify the context in which Soubiran and Coste propose to define the body schema. In 1975, psychomotricity was well on its way to becoming established in the health landscape in France. The State diploma had just been created. The first Training Institutes in Psychomotricity had

only opened their doors a few years ago. And the very young psychomotricity was in the process of making its way to exist alongside powerful psychoanalysis. In these institutional conditions, and equipped with still undeveloped knowledge about the body schema, our two authors anchored themselves in the debates of the time. And it must be said that this notion of body schema hides nothing less than the problem of the links between the body and the mind. How can we think about physiology without thinking about the subject? To make one's contribution to this problem, in 1975, is audacious. It was in fact, at the time, a real vision of what psychomotricity should become. Defontaine (1979) rushes into openness and "physiologis" the body schema

-The body diagram is an almost spatial and visual representation of the body. Little by little, another way of seeing emerged which highlighted the body, no longer as it is represented visually but rather as it acts in the external world: the motor skills and the action of the body in the world become pre-eminent, and it is thus that the We compare the disturbances of the body schema with those of the activity having a purpose, that is to say praxies.

-If we take neurological disturbances as a starting point, we can consider them on three points:

-1/ The body engaged in sensorimotor skills (action on an object in a space): the corporeal schema is linked to ideatory praxis;

-2/ The body is subject to perception in a space that is partly represented but centered on the body. This notion of body schema is linked to the integration of somatognasia: organized gesture takes on a meaning through the body itself, in relation to it and in the space centered on the body. In neurological pathology, these are ideological praxis;

-3/ The body in relation to space and the different parts of space in relation to each other. In neurological pathology, these are constructive praxis."

These three planes allow us to consider the levels of organization and disorganization of the body schema.

The debate became clearer. Defontaine felt confident enough not only to theorize the body schema but also to consider its disorders. Psychomotricity transformed the 1974 essay, the year of the creation of the State Diploma. Of course, it is not possible to look at the body schema without referring to the classic definition of J. de Ajuriaguerra that generations of psychomotor students have learned by heart:

"Built on the basis of tactile, kinesthetic, labyrinthine and visual impressions, the body schema realizes, in a constantly reworked active construction of current and past data, the dynamic synthesis that provides our acts, as well as our perceptions, with the spatial frame of reference from which they take their meaning." »

We will just make a clarification about this definition. The reference to "kinesthetic impressions" is not adapted to current knowledge. Kinesthesia is indeed a part of proprioception. Which is a set of sensory systems allowing the taking of information relating to position, movements (this is kinesthesia) and strength. It is now recognized that the body schema involves proprioception, vision and vestibular sensitivity and that it is to be placed on the side of the organism, as Bullinger (2004) would say. It was Dolto (1984) in France and Gallagher (1986) in the Anglo-Saxon world who would definitively blow the whistle for the end of the game.

2/ Clarity

In France, it was **Dolto** (1984) who settled the debate by referring the body schema to the side of physiological equipment and "anonymity":

- "The body schema is a de facto reality, it is in a way our carnal life in contact with the physical world. Our experiences of our reality depend on the integrity of the organism, or on its transient or indelible lesions, neurological, muscular, bone, and also our visceral and circulatory physiological sensations."

In the Anglo-Saxon world, it is **Gallagher** (1986):

- "The body schema is neither perception, nor a cognitive understanding nor even an emotional apprehension of the body.

- The body schema is an active, operative process of the body, rather than a copy or overall model of the body parts. The schema is the body actively integrating its positions and postural responses into its environment.

- The schema, as an operative process, is the way in which the body meets its environment. It reflects and determines the posture and the general position adopted by the body in its environment. Posture does not equate to an objective position in an objective space. It is a spatialized experience of the body, it is a living space experienced by the body, a living space never fully represented consciously or conceptualized geometrically. The body dynamically organizes its own spatiality by adopting certain postures and situating itself in the environment."

Gallagher calls on Mason (1961) to say that:

- "We are not aware of most of the reactions that occur at very low neurological levels inside our bodies. Coordinating most of the body's physiological and mechanical changes as well as reactions is accomplished by a non-conscious integrative activity called homeostasis.

- In general, and most of the time, physiological processes are non-conscious.

- The body schema is the physiological functioning of the body.

- The body schema is an "anonymous" process. In the image of the body, the body loses its anonymity. It becomes "my" body. My body belongs to me. ""

Since that time, the definitions have changed little:

Holmes and Spence (2004):

- "In order to guide the movement of the body in space, the brain must constantly inform itself of the position and movements of the body in relation to nearby objects. The effective "control" of the body to avoid or manipulate objects with the idea of a behavioral goal to be achieved requires a neurological representation of the body (the "body schema") and of the surrounding nearby space ("peri-personal space")). »

Morin and Thibierge (2004):

- "The brain, and more specifically the right hemisphere, has a non-conscious representation of the body, the body schema, a representation that allows an automatic adjustment of our movements to our spatial environment." »

Shenton et al. (2004):

- "We, along with others, defined the body schema as a permanent, real-time representation of the body's position."

Viaud-Delmon, I. (2007):

- "It is the "egocentric multimodal" space that makes it possible to constitute the body schema on the basis of sensory information. »

- The body schema is a dynamic internal representation of the spatial and biomechanical properties of the body.

- For Paillard (1999), quoted by Viaud-Delmon, the body schema is the situated body. »

De Preester (2008) :

- This author acknowledges the advances proposed by Gallagher. She even paraphrases him: "the body schema can be defined as a system of preconscious and sub-personal processes that works dynamically for postural adaptation and movement; its function is to maintain posture and perform movements without consciously controlling motor activity; it involves a set of motor skills, skills and habits that make movement and posture maintenance possible."

- The body schema involves proprioception. "Regarding posture and movement, it is an important source of information. "

Carruthers (2008) :

- "The body schema [...] would be the real-time or dynamic representation of the body regarding the configuration of the body that can be used to plan and execute a movement."

Fontan (2017):

- "To act effectively, it is necessary to have a precise knowledge of our bodily capacities engaged in action. This knowledge includes the composition of the different parts of the body, the location of the different body segments in space, the relationships between these body segments and the physical limits of the body. This information is found in the brain in the form of internal representations providing information on the characteristics of the action that the body performs and on its interaction with the environment.

- It is obvious that, in order to correctly and accurately generate an action, it is necessary to obtain information on the state of the body. An error from the state of the body would have a direct impact on the movement performed. The example of the use of sensory feedback about the body in action (effectors used, position) suggests the existence of an internal representation of the body acting: *the body schema* (Gallagher 2005).

-To act effectively, it is necessary to know the position of the body in space as well as its geometry and the relationships between the different body segments engaged in the action. This internal representation of body segments in motion has been conceptualized under the term body schema (Head & Holmes, 1911; Dijkerman and de Haan, 2007; Maravita et al., 2003; Naito et al., 2016).

-The body schema would contain information about the acting body, such as its position in space, essential for the execution of actions.

-The integration of sensory information from the body and the environment would therefore play an essential role in the construction of the representation of our own body as well as its relations with the environment. To create an accurate representation of the body in space, the body schema integrates both sensory information generated by the body in motion via the transmission of sensory afferents – *i.e.* vestibular, visual and proprioceptive – and motor information relating to the planning, execution and control of movement. The integration of these different information produced during the action would allow the adult to continuously update the body schema.

-When the body interacts with its environment, multiple sensory information will converge on the CNS. This vestibular, visual and proprioceptive information will provide information on postural changes in the body or on changes related to the environment.

-In summary, the body schema is characterized by a spatial encoding of the body integrating the position and configuration of the body in space, allowing the representations of the action to integrate the modalities of the body acting to achieve a goal. The body schema is a supra-modal entity that integrates the different sensory information coming from the body – *i.e.* vestibular, proprioceptive and visual, thus allowing the creation of a three-dimensional amodal representation adjusted to its environment. The plasticity of the body schema, as observed during the use of tools or in the paradigms of illusion of movement, would allow a continuous and rapid updating in order to adjust the representations of the body to the multiple changes likely to impact the action in a given environment." »

DEFINITION: The body schema is a non-subjective physiological functioning. It is a three-dimensional, non-conscious, automatic and constantly readjusted representation of the overall and/or segmental position of the body and its movements. This representation involves different sensory systems, their coordination and integration (proprioception, vision, equilibration). Proprioception is, in adults, the main reference. The peripersonal space is an integral part of the body schema.

Interoception, i.e. sensitivity from the respiratory, digestive, cardiac and endocrine systems, cannot be included in a definition of the body schema because it is too related to the "manufacture of feelings" (Damasio, 2017) and therefore to subjectivity.

3/ Proprioception

For Breedlove et al. (2012), proprioception is the perception of the body based on the sensory (proprioceptive) *innervation* of muscles, tendons and joints, it informs the brain of the position and movements of the body. For Richard and Orsal (2004), proprioception, also called deep sensitivity, corresponds to three types of sensory information: position (or posture), movement and strength.

- The position information concerns the joint angles. This sensory system allows us to feel the position of the different body segments in relation to each other and therefore, for example, the position of the limb segments between them and in relation to the body. But it also concerns the position of the neck, the orientation of the trunk as well as the opening of the lower jaw. This form of sensitivity is, according to Richard and Orsal, "weak but can be greatly improved by learning."

- Sensitivity to movement, kinesthesia, includes sensations of speed, amplitude and direction. Sensory thresholds are lower in proximal than distal joints.

- Sensitivity to force allows us a certain form of muscular resistance but also a feeling of the muscular effort produced to lift a load.

The sensory receptors involved in proprioception are mechanoreceptors (or proprioceptors) located in muscles, tendons, and joints. In muscles, these are "sensory endings that wrap around the central region of neuromuscular spindle fibers." The neuromuscular spindle comes into action when the muscle is passively stretched. In tendons, the Golgi tendon organs are sensitive to muscle tension and rather insensitive to passive muscle elongations. They are involved during heavy efforts. They therefore record the intensity of the contraction and provide some of the information that contributes to the precise control of movements. Muscle and tendon receptors therefore play a very important role in the control of muscle contraction. Joints are equipped with many types of receptors: Golgi, Manzonni and Pacini corpuscles, the latter being all encapsulated. Other types are reduced to simple free endings. Importantly, all of these receptors provide more information about joint movement than about the angle at which the joint opens. Force receptors appear to be muscle receptors.

4/ The role of vision

Parson (1990) mentions vision as a vital source of information for posture and movement. Gallagher and Cole (1995) studied the role of vision in the development of the body schema. They referred to the situation of IW, an adult subject, suffering from "sensory neuropathy". This person had no proprioceptive or tactile information below his neck. His motor skills were theoretically unharmed. He had no proprioceptive awareness of the position of his limbs. As a result, he could not locate them without seeing them. "Without proprioceptive or tactile information, he could neither know where his limbs are nor control his posture unless he looked at his body with a very great effort of concentration. Without it, he had no control over his movements. »

Gibson (1979) proposes the notion of "visual proprioception" to characterize the role of vision in the intake of information during active movements. This "visual proprioception" would intervene to process the visual flow that an observer moving in space is confronted with. Gallagher and Cole (1995) go further and propose that visual proprioception is involved in the non-subjective processing of visual information related to movements appearing in the visual field and not only when it is the subject himself who moves. "Postural adjustments are made in order to compensate for changes in visual flow. According to Jouen (1988), this ability to process this type of information is present at birth. Gibson's (1979) visual proprioception is therefore reminiscent of Bullinger's (2004) notion of peripheral vision: "Peripheral vision essentially deals with movements. The body's responses to these stimuli are tonic and postural. The movement of a body segment in the visual field is partly regulated by retinal cues. It is essentially the periphery of the retinas that is solicited. The discovery of a "vehicle" body relies largely on peripheral visual signals. »

It is therefore the peripheral visual system, "the vision of movements", that is involved in the body schema.

"When the eye speaks to the hand, their language is space", Bullinger (2004).

There is necessarily coordination between vision and proprioception. Proprioception, as an uncoordinated "mechanical" (for example, when performing a task with eyes closed) to the visual system is obviously a major source of information about - and control of - posture in the here and now. It contributes to the automatic control of posture and movement. But vision plays an undeniable role. IW's proprioceptive deficit undermined sensorimotor coordination between vision and proprioception. Control by peripheral vision replaced proprioception. For IW, the intensity of the concentration required – and its success – to compensate for his proprioceptive deficit by relying on his peripheral vision shows that the latter system is, in a non-sick subject, in fact a support for proprioception.

Vision, in its peripheral component, is indeed part of the body schema.

5/ Balance and the vestibular system

The debates first focused on pathology following the remarks of Bonnier (1902):

-He proposed the term "aschematy" to describe a distortion in the representation of the volume, shape and position of the body and its different segments. Later, Schilder (1968) reported that patients suffering from vestibular disorders reported swelling of their necks during numbness or that their extremities widened or their feet seemed to lengthen. Research has naturally focused on pathology and has shown that vestibular disorders can lead to changes in body schema due to misinterpretations of body signals, for example postural. Sang et al. (2006) and Lopez et al. (2008) state that patients with peripheral vestibular disorders mislocate the different parts of their body. Borel et al. (2004) have shown that patients can underestimate their movements as well as the direction of their movements, passive or active. Schmidt et al. (2013) explain that mild and non-invasive electrical stimulation of the vestibular system improves proprioceptive deficits in cases of right hemisphere injury. The patients in question, suffering from visuospatial hemi-neglect, are thus more precise in the location of their left upper limb. Vestibular signals could provide sensory information capable of correctly locating the limb by involving intact structures also involved in the recalibration of the position of the body and limbs.

What about the subject without any lesion of the central nervous system?

-The same form of stimulation of the vestibular system used in non-pathological subjects not only modifies localization abilities but even creates an illusion of whole-body movement, i.e., a dissociation between perceived and actual localizations (Leggenhager et al., 2008). Bresciani et al. (2002) report that vestibular electrical stimulation disrupts the movements of approaching a visual target by interfering with the subject's own spatial estimation of the position of his hands in the surrounding space.

Neuro-anatomical substrates

-From the outset, it should be noted that there is no cortical area dedicated to equilibration. Vestibular signals reach the vestibular nuclei of the medulla oblongata and are projected onto several multi-sensory regions of the brain (Lopez, 2013). It is believed, thanks to neuroimaging, that the position of the different segments of the body rests on the superior parietal lobe. Somatological representations of the body could involve the parietal operculum but also the posterior part of the insula. These regions are referred to as the "vestibulareto-insular cortex". They are located very close to the temporo-parietal junction (Hashimoto and Iriki, 2013; Leggenhager et al., 2015).

-The vestibular nuclei are the site of a multi-sensory convergence (vision, tact, proprioception). This convergence seems to "drown" vestibular information (Roy and Cullen, 2004).

-The vestibular nuclei project pathways to the oculomotor nuclei, to thalamic nuclei known to be involved in somatosensory processing, and to cortical areas.

-Some of these links provide feedback controls that are used, for example, to turn the eyes to the left and to take into account the proprioceptive signals of the neck during a rotation of the head to the right.

-Lopez (2013) reviews the numerous and integrative vestibulo-thalamo-cortical structures.

Pathology data, studies on healthy subjects as well as our knowledge of the structures of the central nervous system involved allow us to make proposals on the importance of the vestibular system in the body schema.

-Paillard (1991) states that gravitational acceleration is a dominant frame of reference that influences the visual-motor control of our actions and perceptions. "Gravitational signals merge and give coherence to the various frames of reference that underpin action and perception."

-When a subject is asked to grab a target while his chair is rotating, various forces deflect the hand. The vestibular signals generated then make it possible to correct the trajectory of the latter (Guillaud et al., 2011).

-Vestibular signals are used to control our actions and interactions with objects in the environment.

-Vestibular signals contribute to hand localization and movement. The convergence they reflect (their role of multi-sensory integration) maintains a certain form of perception of the body.

-"The vestibular system provides continuous information to the brain to update information about the body's position as well as to maintain its orientation in the surrounding space." (Berthoz, 1996).

-The perception of verticality is based on a multi-sensory integration involving the vestibular system. Walking is a set of actions involving this integration.

6/ Adult neuro-anatomical substrates: the contribution of neuroscience

This paragraph is based on the contributions of Naito et al. (2016) and Fontan (2017). The neuro-anatomical bases of the body schema are to be found in the existence and collaboration of three main networks. Of course, it will only be transcribed here as a simplification, as the structures mentioned should not hide those that have been "forgotten". We must take into account the networks:

-Sensorimotor

-Specialized Parietal

-Fronto-parietal.

These three networks integrate sensory information from the primary somatosensory areas and then converge on the associative parietal areas.

The sensorimotor network is composed of sensory and motor systems aimed at controlling action. "It participates in the kinesthetic processing of information from the limbs" (Naito, 2016). The structures involved are the primary and secondary sensory areas and the primary motor cortex with part of the premotor cortex, the supplementary motor area, the cingulate motor area, the basal ganglia and the cerebellum. This set of structures makes it possible to locate a body modification and to control movement. It is in fact a back and forth between sensory and motor information. The motor cortex (premotor cortex and primary motor cortex) is the site of both descending and upward information. Connected with the parietal cortex, it receives a lot of sensory information. The primary motor cortex "containing a considerable number of corticospinal neurons, both for proximal and distal muscles, is therefore not a simple motor execution center but rather an important node that can contribute to the perception of limb movement by receiving and processing afferent muscle signals [...] The representation of the body carried by this network is most certainly a kinesthetic/dynamic postural model *of the limb*" (Naito, 2016).

For Fontan (2017), "the involvement of the sensorimotor network in the formation of body representations indicates a coupling between sensory and motor representations. These sensorimotor areas will make it possible to precisely locate the bodily changes perceived thanks to their somatotopic organization. »

For Naito (2016), "anterior associative parietal areas are responsible for integrating somatic information from different parts of the body to develop a postural model *of the whole body*. **The specialized parietal network** involves a posterior parietal cortex that is highly connected with the cortical areas processing and integrating the sensorimotor information necessary for movement. It is this activity of multisensory integration that leads Naito (2016) to say that the posterior parietal cortex has a place in the development of the body schema. It records the information coming from the body to precisely locate the position of the limbs, it creates and constantly updates a coherent representation of the body in its entirety but also of the body in contact with the object.

The fronto-parietal network of the right hemisphere is so called because of the close connection between the parietal and frontal areas. It seems to "play a major role in the elaboration of the internal

representations of the body in motion and their conscious access [...] [...] It plays an essential role in the control and supervision of the state of the body, allowing subjects to consciously access their bodily representations in order to be able to act" (Fontan, 2017). Naito (2016) proposes that, "by monitoring and accumulating bodily information and updating the postural model of our body, the fronto-parietal network could carry high-level functions such as self-identification and self-consciousness. This network would be a human specificity, as the monkey does not have one.

In children, things are quite different.

7/ The peripersonal space

Pathology led Brain (1941) to suppose the existence of representations of a space close to the body, the peripersonal space (PEP), and of a distant space, the extrapersonal space. Neurophysiological studies have confirmed this distinction. Rizzolatti et al. (1981) have highlighted the close links between the proprioceptive and visual processing involved in this sector of space.

EPP is defined as the region of space in the vicinity of the body in which objects can be reached and manipulated. The notion of extra-personal space refers to the space beyond, that which involves exploration by eye movements. The representations of EPP are central to sensory guidance of the motor act. The first researchers showed the existence of EPP around the moving hand. In concrete terms, the experimental situation that is a reference is as follows: after immobilization of one arm, the subjects overuse their other arm and modify its representation. The overused limb is perceived to be larger after the immobilization of the other than before. The body schema (D'Angelo et al., 2018) is therefore closely intertwined with a functional representation of the EPP.

It is the experiments with tools that have changed the conception of EPP. Using a tool to act on distant objects, outside of EPP, enlarges the latter. According to Canzoneri et al. (2013), tools can be integrated into the body diagram because: "after using the tool, the perceived distance between two points in the length of the forearm is significantly greater than the perceived distance between two points located in the width of the forearm [...] The perceived length of the limb has therefore increased. According to D'Angelo et al. (2018), "the remote space is integrated into the EPP after the tool is used."

To obtain this experimental effect, it is necessary to present visual or auditory stimuli in the immediate vicinity of the body. The function of the EPP is therefore sensorimotor one. The information processed does not only relate to the part of the body concerned but also to multisensory representations. The EPP is therefore a sensorimotor system at the interface of the body and its environment. It would serve (Noël et al., 2014) as a "bodily boundary allowing adapted reactions thanks to a real-time update and correction of the movement taking into account concomitant sensory feedback [...] It is the action that determines what is coded as near or far. »

For de Vignemont and Ianetti (2014), two types of PPE can be distinguished: that of gesture (a movement with a purpose) and that of protection. Cutting carrots is a gesture, avoiding touching the hot pan serves to protect oneself from burning. "It is plausible to consider the existence of only two PPEs, each with functional and sensorimotor aspects."

Moreover, according to di Pellegrino et al. (2015), the representation of PPE is socially modulated: the presence of a person in the extra-personal space narrows the representation of PPE, as long as this person is deemed "cooperative". In this situation, the representation of the EPP can go so far as to encompass the extra-personal space in which the person is located.

Advances in research have made it possible to highlight a much greater extent of EPP. Initially confined to the space surrounding the hand and upper limb, it is now recognized as extending far beyond. Noël et al. (2014) propose that "the representation of the EPP of the trunk expands in the direction of the front" during walking. This modulation is due to the movements of the whole body and makes it possible to avoid obstacles that loom in our path.

The representation of EPP is based on neurological bases, specifically on the activity of multisensory neurons in the fronto-parietal network that includes the premotor cortex and the posterior parietal cortex (D'Angelo, 2018). These neurons discharge during tactile, visual and/or auditory stimulation presented near a part of the body. For di Pellegrino (2015), "the same neuron that controls hand movements based on skin information can also do so from visual or auditory information." In addition, auditory or visual stimuli in EPP modify the representation of the hand in the motor cortex. For Noël et al. (2014), this phenomenon is possible thanks to the modification of the receptive fields of the neurons of the inferior premotor cortex. "The receptive fields of these neurons grow in proportion to the increase in the speed of the stimulus at the approach. These neurons are therefore specialized in mapping specific sectors of the space surrounding body parts and contribute to the movements of these same body parts.

The representation of the EPP is not the body diagram but it is associated with it.

8/ The evolution of the body schema as the child develops

Although Meltzoff and Moore (1977) hypothesized the existence of a primitive body schema from an early age, we now think of a construction that is closely linked to sensorimotor development. We know that perception influences motor responses. Visual information, for example, affects the child's behaviour. But the opposite is also true: the appearance of new motor skills modifies the perception of the environment. In this way, appropriate behaviours are selected. Perception and action are therefore two intertwined processes. This is known as perception-action coupling. For Assaiante (2019), "early perception-action coupling forms the basis for sensorimotor representations that are essential for intentional, harmonious and adapted motor skills. For Fontan (2017), "the neural bases of perception-action coupling would develop through learning based on sensorimotor experience." This coupling:

- Is functional from birth, its bases are the mirror neuron system (Van Helk et al., 2008);
- Allows, as a final step, "to anticipate the consequences of the action, on the basis of an internal representation of the body in action, with the aim of preserving the effectiveness of the gesture" (Assaiante et al., 2014). This is the body schema.

The child's body schema does not function like that of the adult. Primacy is first given to vision to the detriment of proprioceptive and vestibular information. Especially in the case of sensory conflicts. The immaturity of the parietal and somatosensory areas that manage proprioceptive integration makes them less active before the age of 7. This development continues until adolescence. The cerebellum is involved in children - but not in adults - (Fontan, 2017). It "establishes and consolidates representations of the body in action." The cerebellum disengages as neurological maturation progresses. In this case, it acts as a learning support structure.

The body schema is based on solid coordinations between the visual and proprioceptive systems (see above). This set of coordinations would only take place around the age of 10. However, sensory reweighting – i.e. the modulation of the importance given to a given sensory modality – seems to begin to take place between the ages of 4 and 6: little by little, proprioceptive and vestibular

information increases. The crucial ages, according to Assaiante (2014), are "early childhood, the transition from 6 to 7 years old and adolescence. For the very young, this means that it is during the transitional periods of strong motor acquisition that vision predominates: sitting, standing and walking. Its importance decreases around the age of 7, the age at which the use of vestibular information increases.

We thus note a construction of the body schema that gradually moves from a main reliance on visual afferents to a firm consideration of proprioceptive and vestibular afferents. Fits and starts occur during periods of strong reshuffling during which the processing of spatial information must evolve considerably. The primacy of proprioceptive afferents is not real until the end of adolescence. At this point, the visual system (peripheral vision) has become a support and the vestibular system intervenes at all levels due to its neurophysiological structure.

As for peri-personal space, it is estimated that children aged 5 to 7 already have an efficient representation of it, regardless of the size of the tool used in the research (Caçola and Gabbard, 2012; Gabbard et al., 2007).

9/ Perspectives

Proposals for the development of new tests for the psychomotor assessment of the body schema: imagining an action, performing it actively, performing it passively, YO, YF. Identifying a hand in action on a photo, use of tools, proprioceptive acuity; Proprioceptive acuity can be assessed using protocols to estimate the position of the whole body or specific body segments in the absence of vision.

Conclusions

Neuroscience has therefore provided us with a clear definition of the concept of body schema. Anchored in sensorimotor and spatial coordination, it becomes a way to access the clinical approach. It is consistent with a number of André Bullinger's sensorimotor concepts (peripheral vision coordination and proprioception, sensorimotor coordination in general, importance of postures, notion of space, perception-action coupling, etc.). We will hypothesize here a crucial role of the instrumentation of sensorimotor systems in the development of the body schema, the implementation of the instrumentation being accompanied by an elaborate representation of space.

Many populations of patients requiring psychomotor follow-ups should be able to be supported as closely as possible to their skills and deficits. Psychomotor development disorders, "dys", psychopathologies and psychiatric and neurological disabilities (asomatognosia for example), pathologies of aging and old age. Long classified as psychological phenomena, "out of body experiences" involving vestibular particularities as well as phantom limb problems are also related to disorders of the body schema. It would be important for psychomotor therapists to invest even more in these fields of practice.

In psychomotor skills, it would be appropriate to take into account the existence of the peri-personal space, the neurological foundations of which have been demonstrated. Similarly, neuroscience shows us that the presence of another, even in extra-personal space, influences the dimension of the representation of the EPP, so we must take into account the relational, even tonic-emotional aspect.

Motor ideation tasks where research participants are asked to imagine themselves making a movement or an action are among the most fertile paradigms. Involving mirror neurons and perception-action coupling, this type of task would benefit from being used more in psychomotor skills.

The feeling of deformation (lengthening) of the forearm in the tasks of reaching and grasping an object with a tool are very interesting manifestations of unusual bodily experiences (for the subject of the experiment and perhaps for the neuroscientist but not for the psychomotor therapist). These feelings may be a bridge between certain neuroscience research themes and certain aspects of the body image as it is understood in psychomotor skills. Moreover, and this was not the subject of this article, the body image is taken into account in many of the bibliographical references cited here. This is a different conception of the body image considered in psychomotricity (Pireyre, 2020). But the neuroscientific characteristics of body image include the perception of the body ("body awareness" and "body perception") of the singular and subjective individual, and even its emotional aspect. Perception being the sensation envisaged by the psyche, and CI being subjective and singular, we are not very far from an overlap of the two conceptual fields (neuroscience and psychomotricity).

In addition, body image disorders are also concerned by the neuroscientific conception of the body schema insofar as sensory thresholds that are too high or too low, disorders of "self-attribution" and subjectivity have their origin in sensory functioning and its coordination. Let us understand: schema corporeal. The experiences of fragmentation and collapse are also indirectly linked to it because of their neurological origins: the cortex is aetiological for the former, and the basal ganglia, including the subthalamic nucleus, for the latter.

Reading the bibliographical references, one can see how solid the contribution of neuroscience is to the theoretical foundations of psychomotricity.

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