

Abstract: This text is the second of two and describes new hypotheses on the notion of body schema (BC). Clarified by Dolto [1] and Gallagher [2] who conceptually confined it to neuro-anatomical and neurophysiological equipment, SC has become a field of research for neuroscience. Distinct from the body image, which is an affective given, it concerns, in addition to the motor systems, proprioception mainly, peripheral vision – i.e. the vision of movements – and the vestibular system. Peripheral vision is a support. The vestibular system (antigravity) is concerned with the constant and necessary postural readjustments. Interoception and touch are not involved in the SC, unlike the peripersonal space. Different areas of the central nervous system are involved.

Keywords: Body schema, neuroscience, proprioception, peripheral vision, vestibular system, peripersonal space, neural networks, cortical areas, psychomotor skills.

Introduction

Neuroscience has established that SC concerns the automated management of the body's position in space as well as changes in position. They have highlighted the existence of a neuro-anatomical substrate in SC. The cortical areas involved are varied and organized into neural networks. The clarification of Dolto and Gallagher has proven to be very fruitful. Let's start with some definition sketches.

1/ General definitions

Let's start with Fontan [3]:

- "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 coming 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 [2]).
- 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 [4]; Naito et al. [5]).
- 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 central nervous system. 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 to create 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 illusion of movement paradigms, 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. »

In other words, we need to have real-time sensory information about the position of the different segments of our body in relation to each other. This information can, among other things, ensure a feedback control of the movements made to ensure their effectiveness. It is this form of spatial representation of the different parts of the body in motion that has been called body schema. The latter involves, continuously and in addition to movement planning, the mobilization of the proprioceptive, visual and vestibular sensory systems. The body schema is therefore the result of the coordination of different sensory and motor modalities. It is a sensorimotor concept. With these clarifications in mind, it is now possible to propose a definition of the notion of body schema:

The SC is a non-subjective physiological functioning. It is a sensorimotor, 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 their integration (proprioception, vision, equilibration). Proprioception is, in adults¹, the main reference. What is called "peri-personal space" is an integral part of the SC.²

Interoception, i.e. sensitivity from the respiratory, digestive, cardiac and endocrine systems, cannot be included in a definition of SC because it is too related to the "manufacture of feelings" (Damasio [6]) and therefore to subjectivity³.

2/ Proprioception

For Breedlove et al. [7], 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 [8], proprioception, also called deep sensitivity, corresponds to three types of sensory information: position (or posture), movement and force.

- 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 segments of the limbs 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, "weak⁴ 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 the neuromuscular spindle fibers." The neuromuscular spindle comes into action when the muscle is passively stretched. In the tendons, the Golgi tendon organs are sensitive to muscle tension

1 In children, primacy is given first to vision, as we will see later.
2 See paragraph 6
3 See also De Preester [9].
4 That is to say, not very precise.

and rather insensitive to passive muscle elongations. They are involved during heavy exertion. They therefore register 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 contraction. Joints are equipped with many types of receptors: Golgi, Manzoni and Pacini corpuscles. 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.

Proprioception thus concerns an internal representation of body segments in motion (or following a movement for positional information), an internal representation that was conceptualized under the term body schema by Head and Holmes (1911) [4].

3/ The role of vision

Parson [10] mentions vision as a vital source of information for posture and movement. Gallagher and Cole [2] studied the role of vision in the development of SC. 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." The visual system is therefore an important component of the SC.

Gibson [11] 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 taking place dynamically in space. Gallagher and Cole [2] 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 [12], this ability to process this type of information is present at birth. Gibson's visual proprioception [11] evokes Bullinger's notion of peripheral vision [13]⁵: "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." There is necessarily coordination between vision and proprioception. Proprioception, as an uncoordinated "mechanical" (for example, when performing a task with one's eyes closed) to the visual system is obviously a major source of information on - 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 has undermined sensorimotor coordination between vision and proprioception. Control by peripheral vision has replaced proprioception. For IW, the intensity and success of the concentration necessary 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.

The compensatory nature of peripheral vision in the case of loss of proprioceptive information clearly shows the importance of movement vision in the SC. The case of child development, as we will see

5 Bullinger [13], in the paragraph defining peripheral vision (p.29), quotes Gibson: "Gibson [11] has shown the importance of this primitive component of the visual system." It is therefore not unreasonable to speak of an equivalence between Gibson's visual proprioception and Bullinger's peripheral vision.

later, also supports this idea. Vision, in its peripheral component, is indeed part of the SC.

4/ Balance and the vestibular system

The debates first focused on pathology following Bonnier's remarks [14]:

- He proposes the term "aschematy" to describe a distortion of the representation of the volume, shape and position of the body and its different segments. Schilder [15] reports that patients with vestibular disorders reported swelling of their necks during numbness or that their extremities widened or that their feet seemed to lengthen. Research⁶ based on pathology has shown that vestibular disorders can lead to changes in the SC due to misinterpretations of body signals, for example postural signals. Sang et al. [16] and Lopez et al. [17] state that patients with peripheral vestibular disorders mislocate different parts of their body. Borel et al. [18] have shown that patients can underestimate their movements and the direction of their movements. Schmidt et al. [19] explain that a mild and non-invasive electrical stimulation of the vestibular system improves proprioceptive deficits in cases of lesion of the right hemisphere. The patients in question, suffering from visuospatial hemineglect, 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. And in subjects unaffected by 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. [20]). Bresciani et al. [21] 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.

The pathology therefore clearly shows the involvement of the vestibular system in the SC by misinterpretation of sensory signals. Electrical stimulations of the vestibular system modify the perceived locations of the different parts of the body and disrupt movements. In addition, changes in the center of gravity during changes in position require the involvement of the vestibular system. The vestibular system is therefore well engaged in the SC.

Neuroanatomical substrates

- From the outset, it should be noted that there is no cortical area devoted to equilibration. Vestibular signals reach the vestibular nuclei of the medulla oblongata and are projected onto several multisensory regions of the brain (Lopez [22]). It is thought, thanks to neuroimaging, that the position of the different segments of the body rests on the superior parietal lobe. Somatotopic representations of the body could involve the parietal operculum but also the posterior part of the insula. These regions are referred to as the "parietal-insular vestibular cortex". They are located very close to the temporo-parietal junction (Hashimoto and Iriki [23]; Leggenhager et al. [20]).
- The vestibular nuclei are the site of a multi-sensory convergence (vision, tact, proprioception). This convergence seems to "drown" vestibular information (Roy and Cullen [24]).
- The vestibular nuclei project pathways to the oculomotor nuclei and to the thalamic nuclei involved in somatosensory processing as well as to cortical areas.

- Some of these linkages provide feedback controls used to turn the eyes to the left and take into account the proprioceptive signals of the neck during a rotation movement of the head.

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

- Paillard [25] asserts that gravitational acceleration is a dominant frame of reference that influences the visuomotor 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 catch 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. [26]).
- 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 multisensory 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 [27]).
- The perception of verticality is based on a multisensory integration involving the vestibular system. Walking is a set of actions involving this integration.

The vestibular system is based on multiple neuroanatomical bases. A fundamental reference point in relation to gravity, it participates in the adaptation of movements – of the whole body or limbs – to approach the object to be reached even when the body is in motion and is therefore in a phase of adaptation to changes in the center of gravity.

5/ Adult neuroanatomical substrates: the contribution of neuroscience (Naito et al. [6], Fontan [3])

The neuroanatomical bases of the SC are to be found in the existence and collaboration of three main networks that integrate sensory information from the primary somatosensory areas and then converge on the associative parietal areas: the networks

- Sensorimotor
- Specialized Parietal
- Fronto-parietal.

The sensorimotor network (Naito [6]) is made up of the sensory and motor systems aimed at controlling action. "It participates in the kinesthetic processing of information from the limbs." 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 center of motor execution 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."

For Fontan [3]:

- "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 [6]:

- "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*."

In other words, this network participates in the feedback controls of the movements of the four limbs thanks to ascending sensory information. All the postures of the body are therefore represented at the level of different cortical areas, among other associative ones.

The specialized parietal network (Naito [6]) involves a posterior parietal cortex that is very connected with the cortical areas processing and integrating the sensorimotor information necessary for movement. This multisensory integration activity gives the posterior parietal cortex a role in the development of the body schema. It records information from the body to precisely locate the position of the limbs, it creates and constantly updates a coherent representation of the body as a whole but also of the body in contact with the object.

This network plays more or less the same role as the sensorimotor network, except that it is not limited to relying on kinesthesia but integrates information from various sensory modalities. In this way, it can create a complete cortical representation of the body, including in its contact with objects.

The fronto-parietal network (Naito [6]; Fontan [3]) 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 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 body representations in order to be able to act." "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 *recognition*⁷ and *self-awareness*." By facilitating awareness of representations of the body.

This network is therefore essential to build a conscious cortical representation of the body in motion, which would contribute to the awareness we have of ourselves.

These three neural networks are complementary, the first (sensorimotor network) processes ascending kinesthetic information to elaborate a postural representation of the body in motion. The second (specialized parietal) complements the previous one to include in the body representation the relationship with the object. The third allows us a certain form of self-awareness. We are therefore, by moving from the first to the second and then to the third, faced with an increasing complexity of bodily representation.

7 "The importance of the right fronto-parietal cortex and the inferior parietal lobule in the discrimination of the subject's face from that of others has been reported by numerous studies" (Naito [6]).

6/ Peri-personal space

Brain [28] posits 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. [29] 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 located in the vicinity of the body and 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. Representations of EPP are central to sensory guidance of the motor act. Experimentally, after immobilization of one arm, subjects overuse their other arm and modify its representation. The overused limb is perceived larger after the immobilization of the other than before. The SC (D'Angelo et al. [30]) is therefore closely intertwined with a functional representation of the EPP.

Experiments with tools have changed the design of EPP. Using a tool to act on distant objects, outside the EPP, enlarges the latter. For Canzoneri et al. [31], tools can be integrated into the SC 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 increased⁸." According to D'Angelo et al. [30], "the far space is integrated into the EPP after the tool has been used⁹."

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. [32]) as a "bodily boundary allowing adapted reactions thanks to a real-time updating 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 [33], two types of PPE can be distinguished: that of gesture ("cutting carrots") and that of protection ("not touching the hot pan").

- "It is plausible to consider the existence of only two EPPs, each with functional and sensorimotor aspects."

For di Pellegrino et al. [34], the representation of PPE is socially modulated: the presence of a person in the extra-personal space narrows the representation of the PPE, as long as this person is judged to be "cooperative". In this situation, the representation of PPE can go so far as to encompass the extra-personal space in which the person is located.

Initially confined to the space surrounding the hand and upper limb, it is now recognized as extending well beyond. Noël et al. [32] propose that "the representation of the EPP of the trunk enlarges 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 the obstacles that loom in our path.

The representation of EPP is based on the activity of multisensory neurons in the fronto-parietal network which includes the premotor cortex and the posterior parietal cortex (D'Angelo [30]). These neurons

⁸ This illusion has also been studied using virtual reality. When the "virtual arm is extended, the target to be caught appears closer" (Linkenauger et al. [35]).

⁹ This deformation of the EPP, its plastic character, makes it a different notion from the grasping space (the set of points in space that can be reached without displacement) proposed by Bullinger [13].

discharge during tactile, visual and/or auditory stimulation presented near a part of the body. For di Pellegrino [34]:

- "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 the EPP modify the representation of the hand in the motor cortex. According to Noël et al. [32], 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 increase in proportion to the increase in the speed of the approaching stimulus." These neurons are therefore specialized in mapping specific sectors of the space surrounding the parts of the body and contribute to the movements of these same parts of the body.

The EPP should not be confused with the grasping space mentioned, for example, by Bullinger (2004). For the latter, the grasping space includes all the points of the space that can be reached by the hands without moving the entire body. The apprehension of the EPP, for its part, involves the whole body (and not only the upper limbs) and modifies the bodily representation (enlargement or contraction of a part of the body) in the overall movement. In addition, it implies the activation of other sensory modalities in addition to kinesthesia. The EPP is modifiable, modular if a tool is used. It also allows the feeling of a certain form of bodily limit. Finally, it is "deformable" in the case of the presence of others. EPP is based on well-defined brain structures, particularly on neuronal receptive fields that are adaptable according to movement.

EPP is a sensorimotor notion that makes it possible to "integrate the immediate or more distant spatial environment into the body" under certain conditions. In this way, the management of the space close to the body is facilitated and anticipations become possible. The representation of the EPP is not the SC¹⁰ but it is associated with it.

7/ The evolution of SC over the course of the child's development

Although Meltzoff and Moore [36] hypothesized the existence of a primitive SC 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 a 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. According to Assaiante [37], "early perception-action coupling constitutes the basis for sensorimotor representations that are essential for exercising intentional, harmonious and adapted motor skills." For Fontan [3]), "the neural bases of the 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. [38]);
- 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. [39]). This is the SC.

The SC of children does not function like that of adults. Primacy is first given to vision to the detriment of proprioceptive and vestibular information. Especially in the event of sensory conflict. 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 [3]). It "establishes and consolidates the representations of the body in action." The cerebellum disengages as neurological maturation progresses. In this case, it acts as a structure to support learning.

SC is based on strong coordination between the visual and proprioceptive systems. 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 [39], are "early childhood, the transition from 6 to 7 years of age 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 therefore note a construction of the SC that gradually moves from a main support on visual afferents to a firm consideration of proprioceptive and vestibular afferents. Fits and starts occur during periods of strong reorganization 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 time, peripheral vision has become a support and the vestibular system intervenes at all levels because of 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 [40]; Gabbard et al. [41]).

The SC, the sensorimotor construction of the first years of childhood, goes through a succession of stages. Initially based on - and coordinated with - visual information, he gradually sees the rise of the proprioceptive and vestibular systems. It is around 6-7 years of age that proprioception and vestibular enter the scene. In adolescence, proprioception will take precedence.

Conclusions

Neuroscience has therefore provided us with a clear definition of the concept of SC¹¹. Anchored in sensorimotor and spatial coordination, it becomes a way to access the clinical approach. It is consistent with a number of Bullinger's sensorimotor concepts (peripheral vision/proprioception coordination, sensorimotor coordinations in general, importance of postures, notion of space, perception-action coupling, etc.). We will hypothesize here that the instrumentation of sensorimotor systems plays a crucial role in the development of SC, the implementation of instrumentation being accompanied by an elaborate representation of space.

Many populations of patients requiring psychomotor follow-up 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 CS disorders. 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

11 They still use this terminology of SC, probably to remain in continuity with the work of Head and Holmes (1911), whose importance they recognize more than 110 years later.

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. For example, by developing new assessment tools.

The feelings 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. These feelings may be a bridge between certain research themes in neuroscience and certain aspect of body image as it is understood in psychomotricity. 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 [42]). But the neuroscientific characteristics of the body image include the perception of the body ("body awareness" and "body perception") of the singular and subjective individual, or even his 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 SC insofar as sensory thresholds that are too high or too low, disorders of "self-attribution¹²" and subjectivity have their origin in sensory functioning and its coordination. Let us understand: SC. The experiences of fragmentation and collapse would also be indirectly linked to it because of their neurological origins: parietal cortex for the former, vestibular system and 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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12 This term is used by neuroscience to describe the body's lack of belonging to its "owner". "How did she make the ball to get there?" says this child with ASD, thus showing that his arm does not belong to him.

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