A unity of the self or a multiplicity of locations? How the graphesthesia task sheds light on the role of spatial perspectives in bodily self-consciousness

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Highlights:

The graphesthesia task allows for the investigation of spatial perspectives in touch

Self-centred and decentred perspectives conflict with ambiguous symbols

The adopted perspective depends on spatial, personal, and interpersonal factors

The head-centred perspective is predominant

Perspective-taking plays a crucial role in bodily self-consciousness

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ABSTRACT

Integrating different stimuli, within and across sensory modalities, from a self-centred perspective is crucial for the experience of a unity of the self and the body. On the other hand, understanding the external space and sharing and communicating spatial knowledge with others necessitates adopting different spatial perspectives. How do we juggle these two requirements? In this article, we review those studies that have used the graphesthesia task in order to investigate the perspectives that people adopt when interpreting ambiguous patterns of tactile stimulation (such as the lowercase letters b, d, p, and q) presented on the surface of their body. As these symbols are symmetrical along both the horizontal and vertical axes, one perspective – self-centred or decentred – has to be adopted by participants in order to interpret the different tactile stimuli consistently. A self-centred perspective is centred on the observer's body while a decentred perspective is centred on a spatial location that is different from that of the observer. The results that have been published to date have revealed significant variability across body surfaces and changes in orientation as well as individual differences influenced by personal factors such as gender, spatial abilities, and cognitive style, as well as by interpersonal factors such as dominance or conflict in relationships. Such results suggest that the self can adopt a multiplicity of spatial locations. On the other hand, the head-centred perspective is most commonly adopted across situations, which might be central to account for unification processes. We discuss how these results shed light on the relations between the self, the body, and the external space.

Keywords

Self-consciousness; Spatial perspectives; Perspective-taking; Body; Touch.

1. Introduction

The body and the self are robustly experienced as forming a unity: the self is experienced as delimited by the boundaries of the body. The self is also felt as located at a constant place within the body, predominantly the head or the chest (Alsmith & Longo, 2014; Bertossa, Besa, Ferrari, & Ferri, 2008; Limanowski & Hecht, 2011). Accessing to the external world, which is supposed to be distant from the self, from a unique self-centred perspective relies on this spatial unity between the self and the body. The perception of the world from one unique self-centred perspective is crucial for the phenomenological impression of perceiving the external world as being single and unified, rather than as being multiple or fragmented. Indeed, if we had different perspectives on different parts of the scene, the world would not appear as a single consistent whole. At first glance, these relations between the self, the body, and the external world seem straightforward but several pieces of behavioural, phenomenological, and neurological data demonstrate that the spatial unity between the self and the body is not that simple. Indeed, spatial unity can easily be disrupted in neurological patients or by providing ambiguous multisensory information to the brain (see Blanke, 2012; Dieguez & Lopez, in press, for reviews). Thus, the self does not always appear to be identified with the body and located in the body.

Regarding spatial perspectives, the apparent primacy of self-centred perspectives has been challenged by studies revealing the extent to which people can adopt spontaneously self-centred versus other-centred perspectives (Arnold, Spence, & Auvray, 2016). On the one hand, as interoception is mainly body-centred, adopting a self-centred perspective on external stimuli as well is crucial for self-consciousness, as it allows for the integration of both interoceptive and exteroceptive information into a common egocentric body-centred reference frame (Blanke, 2012; Petkova, Khoshnevis, & Ehrsson, 2011). On the other hand, the adoption of a perspective that is decentred from the body can be advantageous in the case of perspective-taking, when it comes to interacting and communicating with others. Note that it can be argued that perspective-taking also plays an important role in self-consciousness in that it allows understanding that the external world is perceived differently by us and by others. Consequently, perspective-taking may contribute to the distinction between the self and others, which is a crucial component of self-consciousness.

The present article focuses on the role of spatial perspectives in self-consciousness. We review those studies that have used the graphesthesia task, that is, the task of recognizing ambiguous symbols (e.g., the letters b, d, p, and q) drawn on the body surface, in order to investigate the spatial perspectives that are adopted when interpreting tactile stimuli. Tactile stimulations and, more generally, bodily sensations, have recently received special interest in the investigation of self-consciousness with theories focusing on what is called “bodily self-consciousness” (e.g., Aspell et al., 2013). We highlight how the results obtained with the graphesthesia task allow one to further understand the spatial relations between the self, the body, and the external space. We first describe those studies that have highlighted the extent to which the relations between the body, the self, and external space are complex and plastic (Section 2). We then introduce the graphesthesia task and its principles, to underline how it constitutes an excellent paradigm with which to investigate both self-consciousness and perspective-taking (Section 3). Thereafter, we present the main results obtained with the graphesthesia task and show how they reflect the variability of the perspectives adopted as a function of the stimulated body surface and the body configuration but also how they vary as a function of individual preferences (Section 4). Finally, we propose some unification of the apparent variability in spatial location (Section 5) and conclude with some insights concerning how the graphesthesia task may be used in future research to understand further the relations between the self, the body, and the external space, in addition to the already existing methods for investigating bodily self-consciousness.

2. The complexity and plasticity of the relations between the self, the body, and external space

2.1. The plasticity of self-identification to the body and self-location in the body

Three components of bodily self-consciousness have been described (Blanke, 2012): the self-identification to the body (owning a body), the self-location in the body (where I am in space), and the adoption of a self-centred perspective (from where do I perceive the world). The identification of the self with the body can be disrupted in neurological patients. For instance, patients with somatoparaphrenia following a brain stroke can attribute one of their own limbs to another person or, conversely, they can attribute another person's limb to their own body (Gerstmann, 1942). The famous rubber hand illusion (e.g., Botvinick & Cohen, 1998; Ehrsson, Spence, & Passingham, 2004) shows that self-identification can also be disrupted artificially in healthy people. When our own hand (hidden from view) and a fake rubber hand (visible) are stimulated synchronously, we have the illusion that touch is felt on the fake hand instead of our real hand. Proprioceptive drifts have also been reported, with the real hand being mis-located toward the fake hand (Tsakiris & Haggard, 2005).

In somatoparaphrenia and in the experience of the rubber hand illusion, the disruption of self-identification with the body concerns only body parts. A spatial disconnection between the self and the entire body can also occur in different forms of autoscopic phenomena reported by neurological patients, namely autoscopic hallucinations, out-of-body experiences, and heautoscopy (Blanke & Metzinger, 2009; Brugger, Regard, & Landis, 1997). In autoscopic hallucinations, patients have the visual hallucination of seeing a reduplication of their body, which is visualized in front of them, as a mirror reflection of their real body, without self-identification with the reduplicated body. On the other hand, in out-of-body experiences, one's own body is perceived from an external perspective, often from an elevated position, as if the self was no longer located in the real body. As an intermediate case, heautoscopy consists in the feeling of encountering an alter-ego, which is not a simple mirror reflection of the patient's own body. In this hallucination, possibly resulting from a breakdown of the self-other distinction (Heydrich & Blanke, 2013), the patient switches between his own self-centred perspective and the alter-ego's perspective, as if the world was perceived from two places. These different forms of distortions of self-identification with the body, self-location in the body, and adoption of a self-centred perspective, highlight that the different components of bodily self-consciousness can be dissociated (Blanke, 2012) and that there exists a continuum of distortions from simple hallucinations of reduplication of the body through to pure spatial distinctions between the self and the body (Brugger, 2002).

Distortions between the self and the entire body, namely full-body illusions, can also be easily reproduced in laboratory settings, by using ambiguous visuotactile stimuli (Ehrsson, 2007; Lenggenhager, Tadi, Metzinger, & Blanke, 2007). In order to induce full-body illusions, participants are asked to watch real-time videos of their own body or of a fake body (e.g. a mannequin) on a head-mounted display and they are stimulated tactilely on their body surface. When the participants feel the stimulation on their real body and they simultaneously see the stimulation on the virtual body (i.e., the filmed body or the mannequin), they report self-identification with the virtual body and/or self-location in the virtual body. Such experimental distortions can be induced with different spatial perspectives. The virtual body can be seen from an external perspective, as though looking at another person, either from the back (e.g., Lenggenhager et al., 2007) or from the front (e.g., Petkova et al., 2011). The virtual body can also be seen from an internal perspective, as though looking down at one's own body by bending the head forward (e.g., Petkova et al., 2011). The feeling of self-location in the virtual body has been demonstrated to be greater from an internal than from an external perspective (Petkova et al., 2011). Similarly, the RHI is reduced or suppressed when a spatial mismatch is introduced between the postures of the fake and real hand, suggesting that body ownership for limbs rely on a body-centred reference frame (Constantini & Haggard, 2007). Both body-part and full-body illusions have also been reported to strongly depend on temporal synchrony: the illusions of self-misidentification or self-mislocation break down when visual and tactile stimulations are asynchronous (Botvinick & Cohen, 1998; Ehrsson, 2007; Lenggenhager et al., 2007). Taken together, these results highlight the fact that bodily self-consciousness relies on the spatiotemporal integration of both exteroceptive (visual, auditory, and tactile) and interoceptive (proprioceptive and vestibular) stimulations in common egocentric spatial coordinates, which are computed from a self-centred perspective.

2.2. The diversity and unity of spatial reference frames for perceiving the external world

The impression of perceiving the external world from a single spatial origin, i.e., the self, requires a spatial unification of the multisensory information that comes to our body through the different sensory modality. For instance, a fly is often perceived in a multisensory way: we can see it, we can hear the sound of its wings if its flying, and we can feel it when it lands on our body. When experiencing it, we do not only perceive three distinct stimuli but one single unified object, the fly. Multisensory information is thus integrated in space and time, in order to perceive an external world that is spatially organized (Meredith & Stein, 1986). This assumption of unity explains why, in some cases of discrepancies across sensory modalities, illusions can occur as a result of our system trying to solve a conflict, i.e., a break in spatial or temporal unity.

The perception of a unified external world is a complex process because spatial reference frames are very different from one sense to another. Visual information is initially coded in retinotopic coordinates, whereas tactile information is initially coded in somatotopic coordinates, and auditory information is initially coded according to a head-centred reference frame. Spatial diversity is also present within one sensory modality. For instance, the spatial coordinates of tactile stimulation can be defined according to the stimulated body part, to the entire body, or to the external world. These different reference frames can conflict, as revealed by the longer time needed to report which hand, left or right, has been stimulated first when the arms are crossed as compared to uncrossed (Shore, Spry, & Spence, 2002; Yamamoto & Kitazawa, 2001). The additional time taken for localizing touch in the crossed-hand condition has been interpreted as reflecting a conflict between a body-centred and an environment-centred reference frame (Shore et al., 2002).

Finally, the diversity of spatial reference frames is even increased when it comes to planning an action because spatial information is also coded differently for sensors and action effectors. However, spatial information coming from the different senses are integrated into one common and unified reference frame in the goal of performing actions (Cohen & Andersen, 2002). This common reference frame is most often an eye-centred reference frame (Cohen & Andersen, 2002). Spatial information coming from vision (Boussaoud & Bremmer, 1999), audition (Zwiers, Van Opstal, & Paige, 2003), and touch (Harrar & Harris, 2010; Ho & Spence, 2007; Pritchett & Harris, 2011) has indeed been reported to be coded according to the direction of the eyes. The spatial transformation of multisensory information into a common eye-centred reference frame may contribute to the perception of a unified external world rather than multiple worlds. As a consequence, it can also induce the feeling of having one single unified self rather than multiple selves because the world is perceived from one single origin, i.e., from a self-centred perspective.

2.3. A disengagement from self-centred perspectives: the case of perspective-taking

The previous sections have illustrated how both the feeling of spatial unity between the self and the body and the feeling of the spatial unity of the multisensory external world emerge from complex processes. These processes are plastic and disruptions are likely to occur in neurological cases and in ambiguous perceptual situations. We have highlighted that self-centred perspectives are crucial for linking the self to the body and for perceiving a unified external world, spatially distant from the body and the self. However, if self-centred perspectives have primacy in our perception of the world, one can also adopt a perspective that is decentred from that of the self. A decentred perspective can correspond to the spatial viewpoint of another person (i.e., alter-centred, second-person, or third-person perspective), or simply centred at a different location that is not necessarily occupied by another person. Adopting different perspectives therefore facilitates imagining how the environment would be perceived from another point in space, and, importantly, understanding how the environment is perceived by others. Taking others' perspective is crucial for those humans and animals living in social groups because it allows for the sharing and communicating of common spatial knowledge. Perspective-taking is also crucial for self-consciousness as it enables differentiating ourselves from others, and consequently, it reinforces our feeling of being oneself, dissociated from the environment and from the other people with whom we interact.

Spontaneously adopting the perspective of another person has been reported to occur in those situations in which the other's perspective is important, as when communicating with others (Nadig & Sedivy, 2002; Schober, 1993) or in collaborative and interactive situations (Duran, Dale, & Kreuz, 2011; Surtees, Apperly, & Samson, 2016). When we are in interactions with other agents, it is important to take account of their spatial perspective in order to coordinate our actions with them. More generally, when interacting with someone, the environment would be represented in terms of the resources held collectively by both interactors rather than by each individual resource alone (Schilbach et al., 2013, p. 397). For instance, two persons attending to the same object during a collaborative task would use allocentric rather than egocentric representations of the object (Böckler, Knoblich, & Sebanz, 2011), as if the object was represented not only from the self-centred perspective or from the other's perspective, but from a combination of the two perspectives. This influence of interacting with others on the adoption of spatial perspectives or more generally on the way we represent space has been called 'second-person perspective' (Schilbach et al., 2013).

Perspective-taking has also been reported to occur in the absence of communication or interaction with others. The mere observation of another person's action (Thirioux, Jorland, Bret, Tramus, & Berthoz, 2009; Tversky & Hard, 2009), the attribution of mental states to the agent of an action (Zwickel, 2009), or the observation of social scenes (Surtees, Noordzij, & Apperly, 2002) can bias people to adopt the perspective of the person observed, without direct interaction with these people. The spontaneous adoption of the agent of an action's perspective even applies when observing a robot looking at or reaching for an object (Zhao, Cusimano, & Malle, 2016). Merely observing another person has also been reported to spontaneously involve allocentric rather than egocentric representations (Böckler & Zwickel, 2013). In opposition to the 'second-person perspective', the spontaneous adoption of others' perspective, not necessarily influenced by an interaction with the others, is classically called the 'third-person perspective' (Schilbach et al., 2013).

The spontaneous adoption of second- or third-person perspectives in the presence of others highlights the fact that, even though self-centred perspectives are crucial for bodily self-consciousness, self-centred perspectives are not necessarily the default perspective for spatial perception. Adopting the perspective of others can even be the default mode for some people, outside any social interactions, even though a majority of persons spontaneously adopt self-centred perspectives (80% self-centred, 20% other-centred; Arnold et al., 2016). The adoption of self-centred or decentred perspectives may depend on certain personality traits. For instance, those individuals with high social skills adopt the perspective of another person more spontaneously than do those with low social skills (Shelton, Clements-Stephens, Lam, Pak, & Murray, 2012). In addition, dominated people adopt more spontaneously the perspective of another person than dominant people (Galinsky, Magee, Inesi, & Gruenfeld, 2006). On the contrary, spatial perspective-taking abilities are deficient in autistic children (Hamilton, Brindley, & Frith, 2009), high-schizotypal adults (Langdon & Coltheart, 2001), and schizophrenic patients (Langdon, Coltheart, Ward, & Catts, 2001), and those people usually associated with lower social skills (for autism, see Dawson & Fernald, 1987; for schizophrenia, see Mueser & Bellack, 1998) and a lack of self-consciousness (for autism, see Toichi et al., 2002; for schizophrenia, see Daprati et al., 1997).

3. The graphesthesia task: An optimal paradigm to investigate the role of spatial perspectives in the relations between the self, the body, and the external space

3.1. Inferring the perspective taken by participants from their spatial coordinate assignments

The graphesthesia task, i.e., the recognition of ambiguous tactile symbols (e.g., the lowercase letters b, d, p, and q, or the digits 6 and 9) drawn on the surface of the body, provides an excellent paradigm with which to study the perspectives – self-centred and decentred – that are spontaneously adopted when interpreting bodily stimulations. Take the example of the lowercase letter “b” drawn on the forehead by an experimenter facing the participant (see Figure 1A). Recognizing the letter “b” as drawn by the experimenter requires the participant to take a decentred perspective (i.e., decentred from the participant’s position and centred on that of the experimenter). However, because the lowercase letter “b” is ambiguous, it can also be recognized as the mirror-reversed letter “d”, from the participant’s self-centred perspective, as if the letter were to be projected forward and “seen” from the participant’s position. The crucial advantage of using these ambiguous symbols is that an intrinsic orientation of the symbol is impossible to determine and thus one specific perspective has to be taken in order to interpret the symbols. Consequently, when participants try to recognize these symbols, the pattern of their responses can be used to infer the way in which they have assigned the different axes to the stimulus and the perspective they have adopted.

If the participant consistently recognizes the letter “b” when this letter is drawn on the forehead, it can be inferred that the top-bottom axis of the letter has been assigned in the same direction as the participant’s top-bottom axis and the left-right axis in a manner opposite to the participant’s left-right axis (see Figure 1A). These assignments would result from a decentred perspective, as if the letter were to be “seen” on the forehead from an external spatial location (specifically, that of the experimenter). On the other hand, if the participant consistently recognizes the letter “d”, it can be inferred that the letter’s top-bottom and left-right axes have been assigned in line with the participant’s top-bottom and left-right axes (see Figure 1A). These assignments would result from a perspective centred on the participant, as if the letter were to be projected forward and “seen” from the participant’s position. Note that participant-congruent assignments are also compatible with a decentred perspective, as if the letter were to be “seen” from a position located behind the participant’s own head. However, these two perspectives are oriented forward with respect to the participant and they both result in participant-congruent assignments.

What is particularly interesting in the case of tactile perception is that more than one self-centred perspective can be adopted. A self-centred perspective can be centred either on the stimulated body part or on an unstimulated one, usually the head (e.g. Harrar & Harris, 2010). When an ambiguous symbol is presented on a body surface located below the neck (e.g., the trunk), the top-bottom axis can be assigned in the direction opposite to the participant’s top-bottom axis, thus resulting in responses that were rotated by 180° (e.g., to respond “q” when the letter “b” is drawn by the experimenter). According to Sekiyama (1991), these assignments may result from the adoption of a perspective that is centred on the participant's head. Because the stimulated body part is located below the head, the projection of the head axes onto the surface of the trunk may have induced responses that were rotated by 180°, as if the head was bending forward to "see" the tactile symbol on the trunk (see Figure 1B). In Section 4, we will highlight that such a head-centred perspective is very frequently adopted when interpreting tactile ambiguous symbols, possibly due to the predominant role of the head in locating the self.

Two different types of instructions – free and imposed – have been used in protocols involving the graphesthesia task. On the one hand, with free instructions, participants are free to interpret the tactile symbols from any perspective. This type of instruction is used for identifying which perspectives are spontaneously adopted by people under some particular conditions (e.g., as a function of the stimulated body surface, or else under different orientations). On the other hand, imposed instructions are used for evaluating participants' ability to adopt a specific perspective. For instance, the ability to adopt other's perspective or to switch between different perspectives can be evaluated by imposing one specific perspective, and particularly, one that is unnatural for the participant. With free instructions, the proportions of each adopted perspective, as a function of individual differences, and the degree of each participant's consistency can be measured. With imposed instructions, the accuracy and response time when interpreting the symbols from one specific perspective are classically measured.

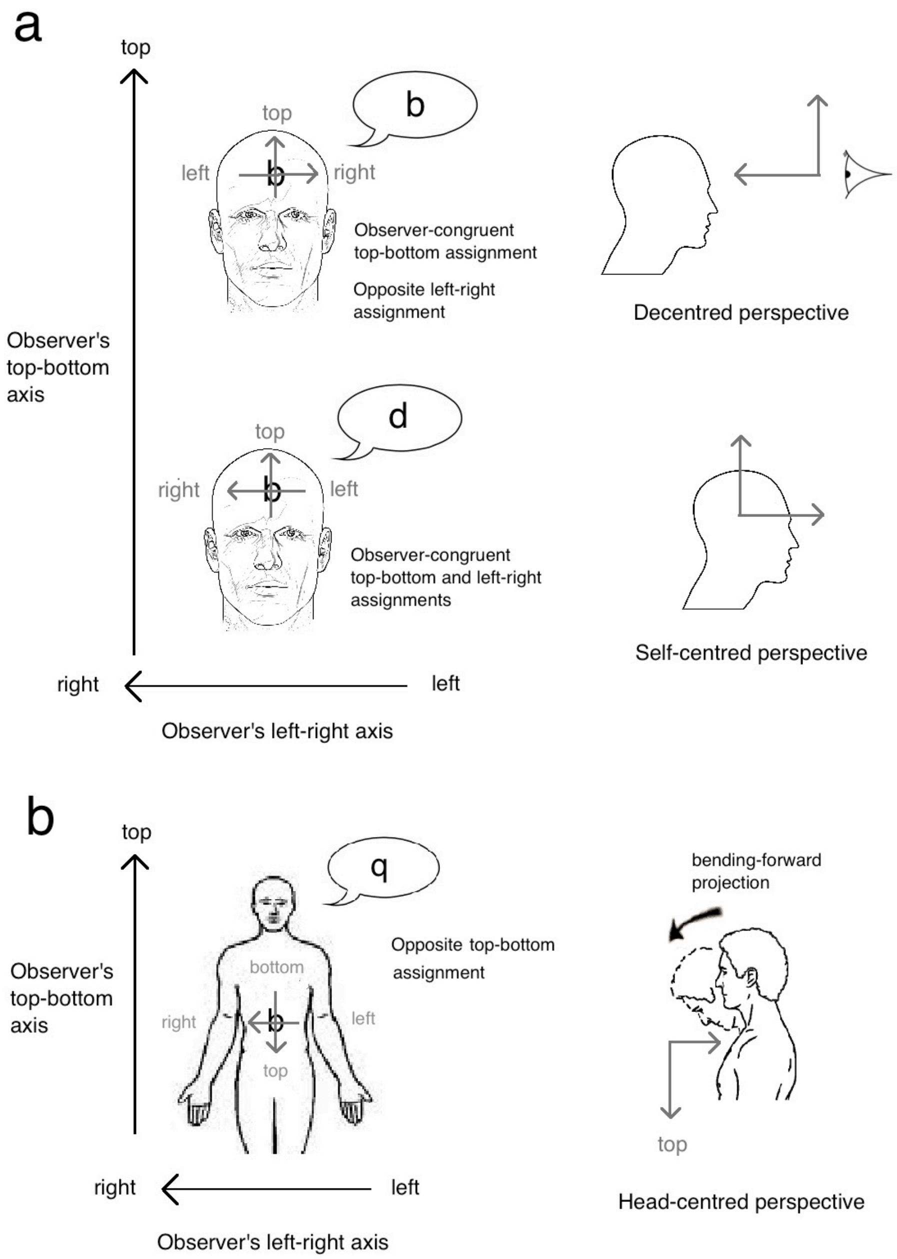

Figure 1: Illustration of the different spatial perspectives that can be adopted in the graphesthesia task, with the example of the tactile letter "b" drawn by the experimenter. (a) When the letter is drawn on the participant's forehead, some participants perceive the letter "b", assigning the top-bottom axis of the letter in the same direction as their own top-bottom axis, but the left-right axis in the direction opposite to their own left-right axis. These assignments may have resulted from a decentred perspective whose origin is located in front of the participant's head. Other participants will perceive the mirror-reversed letter "d" instead, assigning the top-bottom and left-right axes in the same direction as their own body axes. These assignments may result from a self-centred perspective whose origin is located inside the head. (b) When the tactile letter is drawn below the head, here on the stomach, a third perspective centred on the head can be adopted, as if the head was bending forward to "see" the letter on the stomach. As a consequence of this bending-forward projection, the top-bottom axis of the symbol is assigned in the direction opposite to the participant's own top-bottom axis and the participant perceives the 180°-rotated letter "q".

3.2. Investigating self-consciousness and perspective taking thanks to the graphesthesia task

Investigating the spatial perspectives that are adopted in tactile perception is of particular interest to the study of bodily self-consciousness, in particular when targeting the processes that integrate bodily stimulation with external stimuli (e.g., Aspell et al., 2013). Another specific characteristic of tactile perception is the spatial coincidence between the perceiver and the object of perception. Unlike visual stimuli, which are presented at some distance from the perceiver, tactile stimuli occur at the same location in space as the perceiver, i.e., the spatial location of the body. As a consequence, when interpreting tactile stimulation received on the body surface, self-centred and decentred perspectives conflict with one another and there is a choice to be made between perceiving tactile stimulations from the body location (i.e. self-centred perspective) and from an external location (i.e. decentred perspective). Note that ambiguous symbols were also recently used in an analogous visual perspective-taking task (e.g., Surtees et al., 2016). However, as was highlighted in Section 3.1, the graphesthesia task, compared to visual tasks, has the advantage of involving several self-centred perspectives, centred either on the stimulated surface or on a central body part (e.g., the head). We will also describe (see Section 5.1) that these different self-centred perspectives can correspond to a mental localization of the tactile stimulation either on the body (proximal attribution) or on the external space (distal attribution).

Regarding the study of bodily self-consciousness, we believe that the graphesthesia task provides an objective measure of where the self is located (inside or outside the body). During full-body illusions, the most frequently used measure of self-displacement consists in self-report questionnaires. Some objective measures such as bodily reaction (e.g., skin conductance) to aggression of the fake body where the self is felt to be located (e.g. Ehrsson, 2007; Petkova et al., 2011) or proprioceptive drifts in self-localization tasks (e.g., Lenggenhager et al., 2007) are also used. The graphesthesia task provides another measure of self-localization, which has the advantage of providing information about where the self is located and which perspective is adopted, whereas the proprioceptive drift provides a measure of the distance of the self's displacement toward the fake body. More specifically, adopting a self-centred or a decentred perspective in the graphesthesia task corresponds to what happens when locating the self in the body versus decentring from the body, respectively.

Ferrè, Lopez, and Haggard (2014) attempted to use the graphesthesia task as a measure of self-localization in the body. The participants in this study had to recognize the letters b, d, p, and q, drawn on their forehead by the experimenter, while receiving galvanic stimulation of the vestibular system. The authors hypothesized that the vestibular system plays an important role in binding together multisensory information into an egocentric body-centred reference frame. When receiving galvanic stimulation, participants adopted more of a self-centred perspective than a decentred one, compared to a sham stimulation in which no galvanic stimulation was provided. This bias toward adopting a self-centred perspective with galvanic stimulation was interpreted as a reinforcement of the processes of the vestibular system, consisting in anchoring the self to the body. On the other hand, perturbation of the vestibular system may disrupt the unity of the self and the body, giving rise to out-of-body experiences that are characterized by decentred perspectives (see Blanke, Ortigue, Landis, & Seeck, 2002, for the role of the vestibular system in out-of-body experiences). The graphesthesia task, as a measure of which perspectives are spontaneously adopted, can thus provide a reliable indicator of the potential disruption of the link between the self and the body, as people experiencing out-of-body experiences have been reported to adopt more spontaneously decentred perspectives than others (Blackmore, 1987).

It should be noted that in almost all the studies using the graphesthesia task, the symbols have been drawn manually by the experimenter on the participant's body, which biases the results obtained on perspective-taking. Indeed, as the experimenter faces the participant, this might bias them toward adopting the experimenter's perspective, i.e., adopting a decentred perspective, also named second-person perspective. Indeed, having an experimenter biasing the participants allows for the investigation of the role of interpersonal factors in spatial perspective-taking abilities, by varying the quality of the relationship between the experimenter and the participant (see Section 4.2). For instance, the spontaneous adoption of decentred perspectives may depend on the desire and need to adopt or not the perspective of the experimenter. However, when the aim is to investigate pure preference for the adoption of a self-centred or decentred perspective, the use of an automatic device (e.g., a tactile matrix) avoids any bias toward the experimenter's perspective.

4. Main results obtained with the graphesthesia task

So which spatial perspectives – self-centred or decentred – are adopted spontaneously when interpreting tactile symbols? On which body parts (e.g., head or trunk) are self-centred perspectives centred? And what situational, personal, and interpersonal factors influence the ability to adopt different perspectives? In this section, we describe the main results obtained in previous studies highlighting the role of spatial, personal, and interpersonal factors in the adoption of a self-centred or a decentred perspective. When necessary, we indicate whether the self-centred perspective is centred on a specific body part (e.g., the head). Note that we use the term "decentred" to describe any perspective that is not centred on the participant. This can include either a perspective centred on another person (i.e., alter-centred perspective) or a perspective simply centred on a specific point in space, not occupied by another person.

4.1. Spatial factors: body surface and body configuration

The variations of the position and orientation of the stimulated body surface relative to the rest of the body have allowed researchers to investigate how perspectives vary with the configuration of the body. Researchers have investigated whether or not the assignments of the axes depends on the orientation of other body parts than the stimulated one (e.g., the head or the trunk for stimulation on the surface of the hand). Note that ambiguous tactile stimuli have most frequently been presented on the head and trunk because these two locations are often considered as determining the observer's main orientation. They have also been given particular attention by researchers since they can be considered as the subjective locations of the self (Alsmith & Longo, 2014; Bertossa et al., 2008; Limanowski & Hecht, 2011) and, for the head, as the "centre" of other perceptions (e.g., vision).

4.1.1. The head

The results appear very consistent for the surfaces of the head. For symbols drawn on the front and back of the head, with the head oriented looking forward, a predominant adoption of a self-centred perspective appeared very robust and has been found by all studies (see Table 1). This adoption of a self-centred perspective results in assignments of the symbol's vertical and horizontal axes in the same direction as the head's axes (see Figure 1A). Table 1 describes the mean percentages of head-congruent assignments that we computed from previous studies. An important question regarding the perspectives that are adopted when it is the head that is stimulated is whether they are influenced by the orientation of the rest of the body. Parsons and Shimojo (1987) demonstrated that the responses on the forehead and the back do not appear to depend on the orientation of the head with respect to the rest of the body. Parsons and Shimojo's results also indicate that the perspective taken is not influenced by gravity, since the pattern of responses remained unchanged with the head oriented upright and with it oriented upside-down (see also Gurfinkel, Lestienne, Levik, & Popov, 1993).

Compared to the back and front surfaces of the participant's head, different results have been obtained when tactile stimuli have been presented on the left and right sides (Mankin & Weber, 1982; Natsoulas, 1966; Natsoulas & Dubanovski, 1964). When the head was oriented looking forward in the same direction as the trunk, self-centred and decentred perspectives are adopted equally often (see Table 1). In these conditions, the absence of a predominant adoption of a head-centred perspective may be explained by the fact that the orientation of the symbol’s left-right axis is orthogonal to both the head and the trunk’s left-right axes. Consequently, it is equivalent to mentally adopt a self-centred or a decentred perspective. However, when the participant’s head has been turned to the left or right (i.e., the forehead oriented toward the left or the right shoulder, respectively), the assignment of the left-right axis was in the same direction to the left-right axis of the participant’s trunk (Natsoulas & Dubanovski, 1964). Taken together, then, these results therefore show that a self-centred perspective taken to interpret ambiguous symbols drawn on the surface of the head has to be aligned with either the head’s orientation or with the whole body’s orientation, or at least with a combination of the trunk and the head. When such an alignment is not possible, there is an increase of adopting a decentred perspective.

Table 1: Proportions of congruent/opposite left-right assignments for the head surfaces with different orientations of the participant's head. The corresponding response is the letter that would be recognized with the example of the lowercase letter "b" being drawn by the experimenter facing the stimulated surface. The congruent/opposite assignment is defined with respect to the left-right axis of the head for the forehead and the back of the head, but with respect to the left-right axis of the trunk for the lateral surfaces. The top-bottom axis has always been reported to be congruent with the top-bottom axis of the head. The proportions correspond to the mean proportions computed across the various studies.

Surface	Study	Head orientation	Left-right axis	Corresponding response	Proportion
Forehead	Allen & Rudy, 1970 Corcoran, 1977 Deroualle et al., 2017 Duke, 1966 Ferrè et al., 2014 Holmes et al., 1968 Itakura, 1994 Krech & Crutchfield, 1958 Mankin & Weber, 1982 Mori, 2005 Mori, 2012 Natsoulas & Dubanovski, 1964 Parsons & Shimojo, 1987 Sekiyama, 1991 Shimojo et al., 1989	Looking forward	Congruent Opposite	d b	78% 22%
		Looking rightward	Congruent Opposite	d b	69% 31%
		Looking leftward	Congruent Opposite	d b	81% 19%
		Bending forward	Congruent Opposite	d b	97% 3%
		Bending backward	Congruent Opposite	d b	76% 24%
Back	Allen & Rudy, 1970 Corcoran, 1977 Deroualle et al., 2017 Duke, 1966 Mankin & Weber, 1982 Natsoulas & Dubanovski, 1964 Parsons & Shimojo, 1987 Sekiyama, 1991 Shimojo et al., 1989	Looking forward	Congruent Opposite	b d	97% 3%
		Looking rightward	Congruent Opposite	d b	82% 18%
		Looking leftward	Congruent Opposite	d b	93% 7%
		Bending forward	Congruent Opposite	d b	99% 1%
		Bending backward	Congruent Opposite	d b	96% 4%
Right side	Mankin & Weber, 1982 Mori, 2012 Natsoulas & Dubanovski, 1964 Parsons & Shimojo, 1987	Looking forward	Orthogonal Orthogonal	d b	66% 34%
		Looking rightward	Congruent Opposite	b d	71% 29%
		Looking leftward	Congruent Opposite	d b	69% 31%
Left side	Mankin & Weber, 1982 Mori, 2012 Natsoulas & Dubanovski, 1964 Natsoulas, 1966 Parsons & Shimojo, 1987	Looking forward	Orthogonal Orthogonal	d b	47% 53%
		Looking rightward	Congruent Opposite	d b	56% 44%
		Looking leftward	Congruent Opposite	b d	68% 32%

4.1.2. The trunk

Compared to the head, the results obtained when stimulating the trunk were less consistent. Some authors have reported a predominance of self-centred perspective (Duke, 1966), whereas others have documented a predominance of decentred perspective (Parsons & Shimojo, 1987; Shimojo, Sasaki, Parsons, & Torii, 1989). This inconstancy may be attributable to the fact that these authors did not take into account the assignment of the top-bottom axis, either because the symbols utilized were vertically unambiguous (e.g., the letter L), or else because inverted and upright responses were not dissociated, which, as described in Section 3.1 modifies the analysis of the results.

Two studies (Arnold et al., 2016; Sekiyama, 1991) took into account the assignment of the vertical axis, evaluating correctly the adoption of self-centred or decentred perspectives. In these two studies, there was overall a predominant adoption of self-centred perspectives, either trunk-centred or head-centred (see Table 2). However, the adoption of a decentred perspective was quite important in Sekiyama's study, especially when the front or sides of the trunk were stimulated (40% for the front, 46% for the sides). In this study, as in almost all previous studies, the tactile symbols were manually drawn by the experimenter, possibly biasing the participants' responses. Consistent with this hypothesis, in Arnold et al.'s (2016) study, where the tactile symbols were drawn by means of a tactile matrix, only 20% of the participants tested adopted a decentred perspective on the front of the trunk. Any bias toward adopting the experimenter's perspective is thus reduced/eliminated when an automatic device is utilized.

To date, no study has investigated the influence of the head's orientation when stimulating the trunk (i.e., the head has always been oriented forward, in the same direction than the trunk). However, the adoption of a head-centred perspective has been reported to be preferred or to be easier for surfaces that can be easily looked at with real head movements (e.g., the front or the sides) than for surfaces that cannot be viewed directly (e.g. the back) (Arnold & Auvray, in press; Sekiyama, 1991; see also Tipper et al., 1998, for the influence of vision on tactile perception). The head-centred perspective was also harder to adopt for surfaces that were far away from the head (e.g. the shin) and would necessitate a greater quantity of movements (e.g. the sides compared to the front, the legs compared to the trunk), if the head was physically bending forward to see the stimulated surface (Arnold & Auvray, in press). These results can be interpreted as reflecting the fact that the perspective-taking process is of an embodied nature, with the body configuration influencing the perspective we adopt on our own body. The embodied character of perspective-taking may contribute to our phenomenological impression of perceiving the external world as a single consistent whole, as the diversity of the adopted reference frame are unified with a same set of principles, those underlying embodiment.

Table 2: Proportions of congruent/opposite top-bottom and left-right assignments for the surfaces of the trunk. The corresponding response is for the case of the lowercase letter "b" being drawn by the experimenter facing the stimulated surface. The congruent/opposite assignments are defined with respect to the trunk axes. For the front and side of the trunk, the mean proportions were computed only across the studies in which the assignment of the top-bottom axis was taken into account (Arnold et al., 2016; Sekiyama, 1991, for the front; Sekiyama, 1991, for the sides). However, for the back surface, the proportions were computed across all of the studies because Sekiyama's (1991) study revealed no inversion of the top-bottom axis for this surface.

Surface	Study	Left-right axis	Top-bottom axis	Corresponding response	Proportion
Front	Arnold et al., 2016 Duke, 1966 Parsons & Shimojo, 1987 Sekiyama, 1991 Shimojo et al., 1989	Congruent	Congruent	d	37.5%
		Opposite	Congruent	b	30.5%
		Congruent	Opposite (inverted)	q	32%
Back	Duke, 1966 Parsons & Shimojo, 1987 Sekiyama, 1991 Shimojo et al., 1989	Congruent	Congruent	b	96%
		Opposite	Congruent	d	4%
Sides	Parsons & Shimojo, 1987 Sekiyama, 1991	Congruent	Congruent	d	22%
		Opposite	Congruent	b	46%
		Congruent	Opposite (inverted)	q	32%

4.1.3. The hand

For the majority of hand positions and orientations, the horizontal and vertical symbol's axes were predominantly assigned in the same direction to the participant's horizontal and vertical axes, as if a self-centred perspective has been adopted (see Table 3). For instance, when the surfaces of the hands were oriented parallel to the mid-frontal plane, at the height of the head, mirror-reversed responses were observed for forward-facing but not for backward-facing skin surfaces (Corcoran, 1977; Parsons & Shimojo, 1987; Shimojo et al., 1989). This pattern of results was observed to be the same no matter whether the palm or the back of the hand was stimulated. These assignments may well have resulted from the adoption of a head-centred perspective with a projection of the head axes on the hand surface. Tactile symbols drawn on backward-facing surfaces would thus be interpreted as if they were "seen" directly whereas tactile symbols drawn on forward-facing surfaces would be interpreted as if they were "seen" through the hand (i.e., as if the hand was transparent).

Assignments congruent with the adoption of a head-centred perspective, with projection of the head axes onto the stimulated surface, were also observed when the hand was situated below the neck, oriented either parallel to the mid-frontal (Sekiyama, 1991) or to the horizontal plane (Parsons & Shimojo, 1987). Similar results were also obtained with stimulation of the fingertip, with the hand located below the neck and oriented parallel to the horizontal plane (Oldfield & Phillips, 1983).

Finally, when the surface of the hand was oriented parallel to the mid-sagittal plane, that is, when the hand surfaces were orthogonal to the participant's left-right axis, the head axes cannot be directly projected on the stimulated surface. Consequently, the symbols were perceived as if they were "seen" from a decentred perspective directly facing the stimulated surface (Parsons & Shimojo, 1987). This predominance of decentred perspective for the hand oriented orthogonally to the participant may be interpreted in the same way as for the sides of the head when the head is oriented forward (see above). Surprisingly, predominance of decentred perspective has also been reported for stimulation of the fingertip with the hand oriented parallel to the frontal plane, a condition in which the head axes can be projected on the hand (Hartcher-O'Brien & Auvray, 2016). However, in this study, a 3-D automatic device, hold in the hand by the participant, was used. In these conditions, resembling the haptic exploration of a 3-D object, the adoption of a decentred perspective may result from the adoption of an object-centred reference frame (see Newell, Ernst, Tjan, & Bülthoff, 2001, for differences in reference frame for visual and haptic recognition of objects).

Table 3: Proportions of congruent/opposite top-bottom and left-right assignments for the front and back of hands as a function of hand orientations and positions. The corresponding response is for the case of the lowercase letter "b" being drawn by the experimenter facing the stimulated surface. The congruent/opposite assignments are defined with respect to the axes of the trunk. The results are given as a function of the orientation of the stimulated surface rather than as a function of the stimulated surface itself because there were very few reported differences between the palm and the back of the hand. The proportions were computed from the different studies.

Hand Orientation	Hand position	Study	Left-right axis	Top-bottom axis	Corresponding response	Proportion
Parallel to the mid-frontal plane	In front of the body (arm oriented horizontal and forward)	Corcoran, 1977 Parsons & Shimojo, 1987 Shimojo et al., 1989	Congruent	Congruent	b for backward-facing d for forward-facing	96% 82%
			Opposite	Congruent	d for backward-facing b for forward-facing	4% 18%
	Behind the body (arm oriented horizontal and backward)	Shimojo et al., 1989	Congruent	Congruent	b for backward-facing d for forward-facing	73% 64%
			Opposite	Congruent	d for backward-facing b for forward-facing	27% 36%
	Aligned to the mid-frontal plane, above the head (arm along the body, oriented upward)	Parsons & Shimojo, 1987 Sekiyama, 1991	Congruent	Congruent	b for backward-facing d for forward-facing	99% 90%
			Opposite	Congruent	d for backward-facing b for forward-facing	1% 10%
	Aligned to the mid-frontal plane, at the height of the head	Parsons & Shimojo, 1987 Sekiyama, 1991	Congruent	Congruent	b for backward-facing d for forward-facing	99% 90%
			Opposite	Congruent	d for backward-facing b for forward-facing	1% 10%
	Aligned to the mid-frontal plane, below the head (arm along the body, oriented downward)*	Parsons & Shimojo, 1987 Sekiyama, 1991	Congruent	Congruent	b for backward-facing d for forward-facing	54% 20%
			Opposite	Congruent	d for backward-facing b for forward-facing	11% 35%
			Congruent	Opposite	p for backward-facing q for forward-facing	36% 43%
Parallel to the horizontal plane	In front of the body (arm oriented horizontal and forward)	Parsons & Shimojo, 1987 Shimojo et al., 1989	Congruent	Aligned with back-front	b for upward-facing d for downward-facing	93% 84%
			Opposite	Aligned with back-front	d for upward-facing b for downward-facing	7% 16%
	Behind the body (arm oriented horizontal and backward)	Parsons & Shimojo, 1987	Congruent	Aligned with back-front	b for upward-facing d for downward-facing	92% 76%
			Opposite	Aligned with back-front	d for upward-facing b for downward-facing	8% 24%
	Above the head (arm oriented upward)	Parsons & Shimojo, 1987	Congruent	Aligned with back-front	b for upward-facing d for downward-facing	45% 89%
			Opposite	Aligned with back-front	d for upward-facing b for downward-facing	55% 11%
	Below the head (arm oriented upward)	Parsons & Shimojo, 1987	Congruent	Aligned with back-front	b for upward-facing d for downward-facing	100% 96%
			Opposite	Aligned with back-front	d for upward-facing b for downward-facing	0% 4%
Parallel to the mid-sagittal plane	In front of the body (arm oriented horizontal and forward)	Parsons & Shimojo, 1987	Orthogonal	Congruent	b	72%
			Orthogonal	Congruent	d	28%
	Behind the body (arm oriented horizontal and backward)	Parsons & Shimojo, 1987	Orthogonal	Congruent	b	84%
			Orthogonal	Congruent	d	16%
	Above the head (arm oriented upward)	Parsons & Shimojo, 1987	Orthogonal	Congruent	b	65%
			Orthogonal	Congruent	d	35%
	Below the head (arm oriented upward)	Parsons & Shimojo, 1987	Orthogonal	Congruent	b	72%
			Orthogonal	Congruent	d	28%

4.2. Personal factors and individual differences

Although the studies reported above highlight general trends in the perspectives that are spontaneously taken as a function the body surface stimulated and the body configuration, they also reveal some important individual differences for the same body surfaces with the same orientations (e.g., Arnold et al., 2016; Sekiyama, 1991). These individual differences have recently been reported to reflect the existence of a natural perspective rather than being due to an arbitrary choice (Arnold et al., 2016). Thus, as in navigation tasks, where individual participants appear to prefer to adopt either an egocentric or an allocentric reference frame (Denis, Pazzaglia, Cornoldi, & Bertolo, 1999; Gramann, Müller, Eick, & Schönebeck, 2005), individual participants spontaneously adopt different perspectives when recognizing spatially ambiguous symbols. The perspective that is spontaneously adopted has been shown to depend on personal factors such as gender, cognitive style, or spatial abilities, and on interpersonal factors such as conflict or dominance in relationships.

Several studies have investigated gender differences. The results of these experiments have revealed that in order to interpret tactile symbols on their forehead or on the front of the trunk, both males and females predominantly adopt a self-centred perspective. However, a greater proportion of males than females adopt a decentred perspective (Deroualle et al., 2017; Duke, 1966; Krech & Crutchfield, 1958; but see Allen & Rudy, 1970). Males are thus more likely to interpret ambiguous symbols from a perspective that is not centred on their own position and to assign the left-right axis in a direction that is not congruent with their own axis. These gender differences seem incompatible with the reported superiority of females over males in self-consciousness and empathy (Mohr, Rowe, & Blanke, 2010). Females have also been reported to develop more an interdependent self-consciousness whereas males develop more an independent self-consciousness (Cross & Madson, 1997). However, the gender differences in the graphesthesia task can be explained by the greater abilities of males than females in spatial tasks such as discriminating left from right (e.g., Hjelmervik, Westerhausen, Hirnstein, Specht, & Hausmann, 2015) or mentally rotating 3D objects (e.g., Voyer, Voyer, & Bryden, 1995). Gender differences can also be explained by preferences for different strategies (egocentric versus allocentric; route versus survey descriptions) in navigation tasks (e.g., Coluccia, Iosue, & Brandimonte, 2007).

A number of researchers have investigated the development of the adoption of self-centred and decentred perspectives in children (Nagata & Shimojo, 1991; Pedrow & Busse, 1970; Podell, 1966). Researchers tend toward the hypothesis that the perspectives that are adopted in the ambiguous tactile symbol recognition task provide an indication of the developmental tendency to shift from early egocentrism toward a later decentralization (see Acredolo, 1978; Bremner & Bryant, 1977; Piaget & Inhelder, 1953). However, studies using the ambiguous symbol task with children have generally failed to demonstrate a shift from self-centred to decentred perspectives in childhood. Instead, they have revealed that both children and adults predominantly adopt self-centred perspectives when trying to interpret tactile information. However, these studies have revealed that a consistent adoption of a particular perspective by children would appear to depend on their ability to discriminate left- and right-oriented patterns (Itakura, 1994; Nagata & Shimojo, 1991). Up to 4 years of age, left-right indifference is frequent and no consistent perspective is adopted; left-right indifference decreases from 4 to 8 years of age, corresponding to the adoption of a more consistent perspective.

Few studies have highlighted that personality traits and cognitive style influence the perspective that is taken. Cohen and Farley (1973) demonstrated that participants characterized as field-independent individuals (i.e., those with a better ability to discriminate between stimuli coming from the external world versus from inside them) more frequently adopted a decentred perspective whereas those participants characterized as field-dependent individuals (that is, those participants who exhibited less of an ability to discriminate stimuli) more frequently adopted a self-centred perspective instead. Interestingly, individual differences in the adoption of either a self-centred or a decentred perspective when experiencing a full-body illusion has been reported to depend on the weight attributed to vestibular (i.e., internal) and visual (i.e., external) information (Ionta et al., 2011). Those participants who attributed more weight to vestibular information appeared to adopt a self-centred perspective during the illusion whereas those participants who attributed more weight to visual information appeared to adopt a decentred one, as if they were located outside their body and looking toward their body.

The adoption by people of self-centred or decentred perspectives is also influenced by being high or low self-focused (Hass, 1984). In a task similar to the tactile letter recognition task – drawing a letter on their own forehead – participants with high self-focus preferred to draw the letter from a self-centred perspective (i.e., the letter is mirror-reversed) whereas those participants who exhibited low self-focus preferred to draw the letter from a decentred perspective instead. These results indicate that some personality traits have an expression in terms of spatial cognition and being predominantly self- or other-oriented may be a general personality trait that can be measured in different ways, even in simple perceptual tasks such as the tactile letter recognition task.

4.3. Interpersonal factors

Interpersonal factors also influence the perspective that an individual adopts. For instance, decentred perspectives are more frequently adopted on the forehead when the experimenter is located in front of the participant rather than behind him. This shows that the perspective adopted by the participant is biased toward that of the experimenter (Cohen & Lewin, 1986; see also the effect of the presence versus absence of the experimenter described above in Section 4.1). The tendency to adopt the experimenter’s perspective may also reflect some second-person or third-person perspective effects, as interacting with someone or simply seeing someone performing an action biases the observer toward adopting this person's perspective (see Section 2.3).

Interestingly, some mental states such as the feeling of power have also been shown to influence the perspective that participants adopt when they have to draw a letter on their own forehead (Galinsky et al., 2006). Those participants who were in a dominant condition were found to prefer drawing the letter from a self-centred perspective, as if they did not take into account the perspective of others. By contrast, those participants in conditions where they were dominated were more likely to draw the letter from a decentred perspective; that is, as if they took into account the other's perspective instead. Similarly, the adoption of a decentred perspective in this task has been shown to be increased by the feeling of being rejected by others (Knowles, 2014). The adoption of decentred perspectives is also increased when being impelled to deal with another person but is however apparently decreased by the presence of a conflict in the relationship with this person (Steins & Wicklund, 1996). Thus, the perspective that is adopted depends on individual preferences but it can also be influenced by situational factors such as mental states and feelings and by interpersonal factors such as rejection or conflict.

To summarize, the perspective that is taken in the graphesthesia task is influenced by both personal and interpersonal factors, showing that perspective taking depends on spatial abilities but also on personality traits and social situations. As illustrated in Table 4, spatial and social perspective taking appear to be influenced by similar factors, thus supporting the hypothesis that these two processes are closely linked (Erle & Topolinski, 2015; Hamilton et al., 2009; Langdon & Coltheart, 2001; Langdon et al., 2001; Shelton et al., 2012; Zwickel, 2009) and underlied by similar cortical networks (Aichhorn, Perner, Kronbichler, Staffen, & Ladurner, 2006; Schurz, Aichhorn, Martin, & Perner, 2013). What are the possible links between these two forms of perspective taking? Common processes such as disengaging from the self or differentiating ourselves from others – processes that are crucial for self-consciousness – may be involved in the two forms of perspective taking.

Table 4: Personal and interpersonal factors that have been reported to influence individual preferences for centred/decentred reference frames and, more generally, visuo-spatial and social perspective-taking skills.

	Type of factor	Influencing factors	Supporting studies
Preferences for centred/decentred perspectives	Personal	Gender	Duke, 1966 Kretch & Crutchfield, 1958
		Cognitive style	Cohen & Farley, 1973
		Self-focused attention	Galinsky et al., 2006
	Interpersonal	Power	Galinsky et al., 2006
		Cooperation	Steins & Wicklund, 1996
		Conflict	Steins & Wicklund, 1996
Visuo-spatial perspective-taking skills	Personal	Gender	Brunyé et al., 2012 Kessler & Wang, 2012 Mohr et al., 2010
		Aging	Ohta et al., 1981
		Executive control	Wardlow, 2013
		Cognitive style	Brodzinsky, 1980
		Empathy	Mohr et al., 2010 Thakkar et al., 2009
		Autism	Brunyé et al., 2012 Hamilton et al., 2009 Reed & Peterson, 1990
		Schizophrenia	Langdon & Coltheart, 2001 Langdon et al., 2001
	Interpersonal	Familial situation	Mohr et al., 2013
		Cultural collectivism/Individualism	Mohr et al., 2013 Wu & Keysar, 2007
Social perspective-taking skills	Personal	Cognitive style	Davis & Kraus, 1997
		Intelligence	Davis & Kraus, 1997 Selman, 1980
		Autism	Hamilton et al., 2009
		Maltreatment	Burack et al., 2006
	Interpersonal	Cooperation	Deutsch, 2000 Johnson, 1975
		Attractiveness	Ickes et al., 1990
		Familiarity	Stinson & Ickes, 1992

5. A multiplicity of spatial perspectives but a unity of the self

The results of the studies using the graphesthesia task reveal a significant variability of the spatial perspectives adopted when interpreting bodily sensations. People adopt self-centred or decentred perspectives, as a function of the stimulated surface, the body configuration, personal, and interpersonal factors. Moreover, contrary to vision, several self-centred perspectives are possible, centred either on the stimulated surface or on a central body part, usually the head. So, how to reconcile this multiplicity of spatial perspectives with the feeling of a unity of the self resulting in a feeling of a unity of the external world? In this section, we propose a unification of this variability in perspective, first by highlighting the important role of the head in the assignment of spatial coordinates to tactile stimulation, and second, by emphasizing the role of perspective-taking in self-consciousness.

5.1. The importance of the head axes

The results described above highlight the importance of the head axes when interpreting ambiguous tactile stimulation. When the head is stimulated, the orientation of the rest of the body does not influence tactile perception. By contrast, when the rest of the body is stimulated, the top-bottom and left-right axes of the tactile symbol are most often assigned in the same direction as the head axes. According to Parsons and Shimojo (1987), the importance of the head, which contains most of the sensory apparatus, is due to its role as a "pilot" for action planning. Some authors also refer to the special status of the head in the subjective localization of the self (Alsmith & Longo, 2014; Bertossa et al., 2008; Limanowski & Hecht, 2011) in order to explain the central role of the head (Cohen & Lewin, 1986). A similar influence of head orientation has been reported in spatial tasks involving different sensory modalities (see Section 2.2). According to Cohen and Andersen (2002), spatial information is integrated across the senses by transforming multisensory spatial information into a common visual reference frame in the goal of performing actions. Multisensory integration is also facilitated when a head-centred rather than a decentred perspective is adopted (Pozeg, Galli, & Blanke, 2015). The important role of the head may thus reflect the dominance of vision in the multisensory integration processes that underlie bodily self-consciousness (Faivre, Salomon, & Blanke, 2015). For instance, in the RHI, the visuo-tactile conflict is resolved by attributing the visible fake hand rather than the invisible real hand to the body.

The predominance of the head-centred perspective in the graphesthesia task may thus reflect a visual dominance in the interpretation of tactile information. Especially, as the ambiguous symbols that are used are most of the time alphanumerical symbols, which are usually perceived visually rather than via touch. Relevant to this hypothesis, Shimojo et al. (1989) investigated the role of previous visual experience in tactile symbol recognition, by comparing sighted and both congenitally and early blind participants. Their results revealed that the perspectives that were adopted by these two groups of participants were overall the same, which goes against a role of prior visual experience. However, these results should be taken with caution, as the authors have not taken into account the top-bottom axis for the interpretation of tactile symbols.

Adopting a head-centred perspective for interpreting tactile stimuli does not necessarily imply the conversion of the stimuli into a visual format. However, both visual and tactile perspective taking seem to involve a common externalization process: the origin of the perspective must be located at a different position than the object of perception. In vision, the object is external to the perceiver, located in front of the head. In touch, the externalization process involves projecting the tactile stimulation forward, centring the perspective on another body part than the one being stimulated (i.e., bending the head forward to see the stimulation), or adopting a decentred perspective. The adoption of a consistent spatial perspective on tactile stimulation may thus characterize the transition from experiencing the tactile stimulation on the skin (proximal attribution) to becoming able to gain access to the distant object represented by the tactile stimulation (distal attribution). This distal attribution process, also named referral of touch (e.g., Petkova & Ehrsson, 2009), is crucial for the ability to distinguish internal from external stimulation, and more generally, the self from the external world. Interestingly, such distal attribution processes occur when using those visuo-tactile conversion devices that convert visual stimuli into tactile stimulation. Trained users of such devices report attributing tactile stimuli directly to external objects (see Hartcher-O'Brien & Auvray, 2014, for a review).

5.2. The role of perspective taking abilities for self-consciousness

Even if self-centred perspectives are predominant in the graphesthesia task, decentred perspectives are also quite frequent, particularly when the experimenter is facing the stimulated surface, biasing the participant toward adopting his perspective. This bias corresponds to what has been called adopting a second- or third-person perspective (Schilbach et al., 2013), that is, taking into account the perspective that someone with whom we interact has on the external world. These perspective-taking abilities are particularly crucial for humans and animals living in society, as they enable understanding how the world is perceived by others. It has been highlighted that some interpersonal factors such as the feeling of being dominated or rejected contribute to the impelling of taking into account other's perspective (see Section 4.3), possibly as a solution to overcome such an inferior position in a group.

If decentred perspectives are crucial for social interactions, they can also directly contribute to the emergence of self-consciousness. Indeed, being able to understand that the world is perceived differently by others reinforces the feeling of being oneself, distant from both the others and the external world. Some distortion of self-consciousness such as heautoscopy has been described as resulting from a breakdown in the distinction between the self and others (Heydrich & Blanke, 2013). According to this view, if decentred perspectives often characterize some distortions of self-consciousness, the adoption of a decentred perspective should not be seen as necessarily reflecting a deficit of self-consciousness. On the contrary, two different causes leading to the adoption of a decentred perspective should be distinguished: being able to switch between different perspectives, thereby being able to adopt the perspective of others when necessary versus being biased toward adopting a perspective decentred from the self. For instance, people having out-of-body experiences have been reported to be biased toward describing dreams from a decentred perspective rather than a self-centred one (Blackmore, 1987). One can thus predict that a similar bias will be found with the graphesthesia task when people are free to adopt any perspective they want. In addition, people experiencing out-of-body experiences and people suffering from a greater deficit of self-consciousness such as heautoscopy may have difficulties when being imposed to adopt a self-centred perspective.

6. Conclusions

Research on the graphesthesia task sheds light on the factors influencing the spatial perspectives that are adopted when interpreting tactile patterns such as alphanumerical symbols. The review of these studies highlights that the graphesthesia task is an excellent paradigm with which to investigate the role of spatial perspectives in self-consciousness. The use of tactile stimulation is particularly relevant for bodily self-consciousness. The studies reviewed here reveal an important variability of the spatial perspectives that can be adopted, a variability that would appear ro be even greater than in the other sensory modalities, such as vision. This variability is apparently incompatible with the feeling of perceiving the world from one unique perspective, which is an important aspect of self-consciousness. However, general trends reveal the central importance of the orientation of the head axes when it comes to adopt a spatial perspective on tactile stimulation provided to most body surfaces. The importance of the head axes is in line with the major influence of both the head and the visual processes in multisensory perception and may reflect the specific status of the head in the subjective location of the self.

The studies reviewed here also reveal important differences between participants with some preferring to adopt a self-centred perspective and others a decentred perspective instead. The fact that this preference is influenced by several personal (gender, cognitive style, self-focused attention) and interpersonal (power, cooperation, conflict) factors leads us to the hypothesis, to be confirmed by subsequent experimental investigations, that spatial perspective taking may be a spatial expression of certain personality or cultural traits. We also argue that the ability to adopt a perspective that is decentred from the self and the body contribute to self-consciousness as perspective-taking processes are crucial to understanding how the world is perceived by others and to distinguish the self from others.

Finally, the graphesthesia task offers an interesting tool with which to better understand the distortions of bodily self-consciousness such as out-of-body experiences and heautoscopy. For instance, it can be used, together with the multisensory full-body illusions that induce self-identification to an avatar, in order to better characterize the spatial perspectives that are involved during the illusion. It may also potentially provide the basis for future tools designed for the diagnosis of atypical developmental social cognition such as autism and help better designing tactile interfaces such as sensory substitution devices.

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