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Is there a tactile field?

It is commonly acknowledged that there is a significant overlap between the contents of visual and tactile experiences. In particular, many objects and their properties may be experienced both by using touch and vision. For instance, we may see and also touch a chair, and in doing so, each of the modalities can inform us about its features, such as shape or size. Nevertheless, even though vision and touch may present the same objects and properties, it seems that in the case of each of these modalities the items considered are presented in a significantly different way. For example, tactile experiences of external objects are mediated by interoceptive bodily sensations; this does not happen in case of visual experiences, which intuitively seem to be purely exteroceptive (Martin, 1993; O'Shaughessy, 1989; Ratcliffe, 2008; Richardson, 2011). Furthermore, while vision presents spatial properties, such as shape, in a mainly synchronic way, the tactile experiences of shape have an important diachronic aspect, as the shape of objects is recognized by exploratory activities in which different parts of an object are touched at subsequent moments (Fulkerson, 2014; Klatzky & Lederman, 2004; Martin, 1992).

One of the most important differences concerns the way in which space itself is presented in visual and tactile modalities[1]. In the case of vision, it is commonly accepted that

[1] I write about 'presenting space' in order to stay neutral on the specific theory of perceptual experiences. Depending on a theory, experiential space may be treated as a part of representational content, as a part of experiential structure, or as a physical object which constitutes perceptual experiences.

visual objects are experienced as located in a bounded ‘visual field.’ The character of the visual field makes it possible not only to perceive objects as standing in spatial relations, but also to experience empty space, which extends between objects, and through which distant objects are seen (Mac Cumhaill, 2015; Martin, 1993; Richardson, 2010).

It is controversial whether similar field-like characteristics can be attributed to the space in which tactile objects and tactile sensations are experienced to be located. Some authors believe that touch also has abilities to present empty spaces (e.g., Ratcliffe, 2008; Mac Cumhaill, 2017; Scott, 2001) and that certain bodily representations provide a foundation for locating tactile entities in a field-like space (Cheng, 2019; Cheng & Haggard, 2018; Haggard & Giovagnoli, 2011). However, there are also important positions in which the existence of a tactile field is denied, for instance due to the diachronic way in which touch operates and difficulties in discerning tactile experiences of an empty space from an absence of tactile experience (see Martin, 1992; 1993; O’Shaughessy, 1989; Strawson, 1959).

In the paper, I aim to investigate whether it is justified to postulate that space in which tactile objects and tactile sensations are experienced to be located has the form of a field. I argue that the answer is both ‘yes’ and ‘no’. This is so due to the dual nature of touch: touch is both an interoceptive modality, which presents states of one’s body, and an exteroceptive modality, which presents external entities. I claim that the interoceptive tactile space, in which tactile bodily sensations are experienced to be localized, has the character of a spatial field. On the other hand, the exteroceptive tactile space, in which external, tactile objects are experienced to be localized does not have characteristics necessary for ascribing field status.

The paper starts (section 1) by explicating the notion of ‘spatial field’. Subsequently, a distinction between interoceptive and exteroceptive tactile spaces is introduced in Section 2. In Section 3, I argue that the interoceptive space, in which tactile bodily sensations are experienced to be located, has the character of a spatial field. Finally, in Section 4 I argue that the analogous conclusion is not justified in the case of exteroceptive tactile space.

1. Types of spatial representations

There are at least three, nonexclusive types of perceptual spatial representations. First, a perceptual modality may present the spatial properties of some entities. For instance, vision presents objects as having certain shapes and sizes. Second, a perceptual modality may present spatial relations between perceived entities or between perceived entities and a subject. Finally, it may be perceptually presented that perceived entities are located in a spatial field. When one visually perceives two objects positioned at some distance from each other, these objects are not only experienced as standing in a spatial relation, but also as localized within a space designated by the boundaries of our visual field, and as separated by, also visually presented, some empty locations positioned between them.

As shown by the visual examples above, a single perceptual modality can exhibit various abilities for forming spatial representations: it can present the spatial properties of entities, present entities as standing in spatial relations, and present them as located in a spatial field. However, this is not universally the case, as some modalities may have more restricted abilities for spatial representation. For instance, while it is plausible that audition presents entities as standing in egocentric spatial relations, like being to the right of the subject, it is less likely that audition presents entities as positioned within some sort of auditory spatial field (see O‘Callaghan, 2008; O’Shaughnessy, 2009; Nudds, 2009 for various positions on auditory spatial representation).

The question of whether tactile entities are presented in a way that allows us to speak about a tactile field is controversial within the philosophical literature (Cheng & Haggard, 2018; Martin, 1992; 1993; Scott, 2001). The first step required to resolve this issue is to provide a more precise characteristic of properties which distinguish spatial fields from other types of spatial representations. As an example, let's consider an ordinary visual experience in which two circular objects are presented as positioned at some distance from each other. The main intuition concerning the presence of a visual field is that such objects are not presented merely as having spatial properties and as standing in spatial relations, but are presented as positioned within a topologically connected space with a roughly conical shape. This space seems to constitute a 'container' or 'form' (see Cheng, 2019) in which perceived objects are located, and which remains structurally unchanged despite the appearances and disappearances of objects, as well as modifications of their spatial arrangement. In other words, the presence of a visual field is a structural feature of visual experiences which remains the same no matter what arrangement of objects is perceived (see Richardson, 2010)[2].

Topological connectedness means that there is a path composed of locations between each two places within the visual field, such that each element of the path is spatially connected to the previous element. In other words, there is a possibility of reaching, by spatially continuous movement, any location within the visual field from any other location within it, without crossing its borders. I believe that topological connectedness is one of the crucial characteristics of spatial fields. Due to its presence the perceived items are not only experienced as being at some distance, but also as separated by a path of connected, or overlapping, locations (which may be empty or occupied by some other items). Without topological connectedness, it would be difficult to maintain the intuition that a spatial field is a common 'container' which encompasses presented entities. Thus, I assume the following topological connectedness rule:

[2] This is not to deny that there are disorders, such as Bálint's syndrome or tunnel vision, which may lead to visual experiences in which visual field is distorted, or visual space does not have the form of a field.

(Topological Connectedness) *If a perceptual modality presents entities as located in a spatial field, then it presents them as located in a topologically connected space.*

The second crucial characteristic of visual field is that its topological structure is independent from experienced patterns of spatial relations between perceived entities. For instance, in the case of vision, one may initially experience an object *A* at some distance from an object *B*, then an object *C* may appear, which also stands at some distance and direction from *A* and *B*, and finally objects *A* and *B* may disappear, and only object *C* remain. However, despite these changes in spatial relations, the topological structure of the visual field remains unchanged. In particular, it is not the case that visual objects are presented as located in a topologically connected space only when some specific arrangement of visual entities is perceived. I believe that such 'relation independence' is another necessary characteristic of a spatial field. Without satisfying this condition, the spatial field would not be a 'container' in which various spatial arrangements of entities may be located, but instead, its structural features would rely on certain arrangements of entities. This condition is expressed by the following rule:

(Relation Independence) *If a perceptual modality presents entities as located in a spatial field, then the topological structure of space in which entities are presented as located is the same no matter the experienced spatial relations concerning the presented entities.*

The third essential characteristic of spatial field is the possibility of empty locations, i.e. such locations which are not occupied by any presented entity. When we perceive objects positioned within visual field, we may also perceive that there are some empty spaces between spatially related objects, or empty locations between objects' positions and our location. If a perceptual modality is not able to present empty locations, again, space would not be presented as an independent 'container' in which objects are located, but rather as a spatial arrangement of some entities. Because of that, I postulate the following Possible Emptiness rule:

*(*Possible Emptiness*) If a perceptual modality presents entities as located in a spatial field, then it presents them as located in a space which may contain empty locations.*

I treat the three above necessary rules as jointly sufficient for perceptually presenting entities as located in a spatial field. This means that a spatial field is a space which is a topologically connected arrangement of places such that its structure is not modified by changes concerning spatial relations between entities, and which may contain empty locations. By using the rules above, we may formulate a criterion that must be satisfied by a perceptual modality in order to present entities as located in a spatial field:

(Spatial Field) *A perceptual modality presents entities as located in a spatial field if and only if (a) it presents them as located in a topologically connected space, (b) the topological structure of space in which entities are presented to be located is the same no matter the experienced spatial relations concerning the presented entities, and (c) it presents them as located in a space which may contain empty locations.*

The above characteristic of the spatial field is able to explicate the main metaphor, according to which, spatial field is a 'container' or a 'form' in which some entities may be presented. A container constitutes a topologically connected space; it provides a stable structure in which various arrangements of entities may be located, and some of its parts may be empty. Furthermore, the proposed characteristic grasps the major, intuitive features of the visual field which is a paradigmatic example of the perceptual spatial field. In visual space, each location is connected with every other location by a possibly empty spatial path, such that an entity may travel between any fragments of the visual field in a continuous fashion. Furthermore, we do not experience visual space undergoing any structural modifications when perceived objects change their positions and relational arrangements.

I assume that the above characteristics of visual field are perceptually presented in experiences. Alternatively, one may oppose that assumption by providing a distinct account, according to which what is presented are objects standing in spatial relations and field-like characteristics are recognized in virtue of post-perceptual, propositional states (see Mac Cumhaill, 2015 for considerations regarding this view). While the detailed discussion cannot be accommodated within this paper, I believe, following Richardson (2010), that there are reasons to accept that there is a perceptual phenomenal character concerning field-like visual space. First, visually perceiving empty fragments of visual field is distinct from the lack of a visual experience. For instance, we do not have any visual experience of space behind our head, but there is some way in which empty locations within the visual field look to us. Second, there is a phenomenal difference between seeing whether visual space extending between two objects is empty or occupied by other items. The presence of this difference suggests that there is some phenomenal character connected with experiencing empty visual space.

In empirical literature (in particular, see Haggard & Giovagnoli, 2011), the notion of tactile, spatial field is introduced mainly to explain the ability to recognize patterns of relations between tactile sensations. Such patterns are static, so are recognized without the help of temporal factors, and are big enough such that their elements are present in nonoverlapping receptive fields of tactile receptors. The notion of spatial field introduced above can account for the perception of such patterns, because the presence of topologically connected and structurally stable space allows for simultaneously presenting that there are several elements occupying spatial locations and standing in certain spatial relations, for instance concerning distance. Nevertheless, in Section 3 I argue, contrary to what is often postulated in empirical and philosophical works, that the ability to recognize tactile patterns is not sufficient as a justification of the presence of a tactile field.

Later, I argue that the Spatial Field criterion is satisfied in the case of the tactile interoceptive space, but not the tactile exteroceptive space.

2. Interoceptive and exteroceptive tactile spaces

In my understanding of touch, I follow those authors who characterize it as a complex modality that uses a variety of data, in particular, that provided by cutaneous, kinesthetic, and proprioceptive mechanisms (e.g., Fulkerson, 2011; Lederman & Klatzky, 2009; O'Shaughnessy, 1989; 1998; Ratcliffe, 2012). This diversity of information, in important part gathered through active exploration of the environment, is what allows touch to form elaborate representations of external objects.

A commonly recognized aspect of tactile modality is its bipolar exteroceptive and interoceptive character (e.g., Mattens, 2013; 2016; Ratcliffe, 2008; Richardson, 2011). This bipolarity means that tactile perceptual states usually present something about external entities (exteroceptive aspect) and about states of one's body (interoceptive aspect). For instance, in a tactile experience related to the act of holding a ball, an external object is presented as a common subject of various features such as hardness, roughness, size, and shape (Fulkerson, 2011; 2014). Simultaneously, such an experience has also an interoceptive aspect, as it presents that there is pressure applied on surface of the hand, and that the hand is in a particular position. In fact, it is often claimed that the exteroceptive tactile perception of objects is mediated by interoceptive tactile bodily sensations (Martin, 1993). For instance, the phenomenal character of tactile bodily sensations may be such that it implies the presence of an external entity (e.g., a sensation of pressure implies that something applies this pressure, see Richardson, 2011) and it may mirror the properties of external entities such as their shape (e.g., we may experience a pressure sensation as located in a circular fragment of skin, see Martin, 1992).

The dual character of touch has also an implication for the way in which tactile entities are spatially represented. First, tactile space may be understood as an exteroceptive space in which external entities, such as a held ball, are experienced to be located. However, tactile space may also be understood as an interoceptive bodily space in which tactile bodily sensations are experienced to be positioned. Here again, I understand tactile spaces in a broad way, as constructed using various sensory data involving cutaneous, kinesthetic, and proprioceptive information. However, this is not to deny that even mechanisms processing merely cutaneous information may allow for formation of elaborate tactile spatial representations (see Cheng, 2019; Haggard et al., 2017).

To illustrate the difference between exteroceptive and interoceptive tactile spaces, let's consider two tactile experiences. The first experience, "Short," is an experience as of holding a short stick between the thumb and index finger. The second, "Long," is an experience as of holding a longer stick between those fingers, such that the thumb and index finger are significantly further apart. Other factors relevant for tactile perception, like the current position of various body parts, are the same in both Short and Long.

Experiences Short and Long have an exteroceptive spatial aspect: they present sticks as positioned in space extending beyond the bodily boundaries. However, each of these experiences presents the ends of a stick as located in different parts of the external space. It is so because in Short, the ends of a stick are positioned closer to each other than in Long. This point is particularly apparent if one considers a transition from Short to Long, as would occur if the stick expanded and pushed the fingers further apart. After the extension, the endings of a stick would be experienced as located in different places than their initial positions. This shows that exteroceptive touch utilizes some form of an external reference frame. Nevertheless, it is not clear whether such a spatial frame is merely relational, such that only relations between body parts and touched objects are represented, or whether it is a genuine, topologically connected spatial field.

Apart from the exteroceptive aspects, both Short and Long have also an interoceptive spatial aspect: they present tactile bodily sensations on index finger and thumb. In one sense, these sensations are also presented as located in the external space, roughly in places in which fingers are positioned. However, in another sense, which is the one relevant here, the sensations considered are presented as located in the interoceptive, bodily space determined by the stable structure of the body. In the case of this interoceptive bodily space, the presented locations of sensations are the same no matter whether we consider Short or Long. Both experiences present a sensation on an index finger and a sensation on a thumb that are spatially separated by the same bodily fragment, encompassing the fingers considered and part of the hand. Using the terminology introduced by Bermúdez (1998, pp. 154-161), we may state that the locations of tactile sensations in interoceptive space are ‘A-locations.’ Spatial relations between such locations are not affected by the current position of body parts, but rather, are determined by the stable way in which body is divided into parts by joints.[3] In

[3] Bermúdez contrasts A-location with B-locations which are determined by the current relational arrangement of the body. For instance, a tactile sensation on a foot has differing B-locations depending on whether a leg is straight or bent.

contrast to the case of exteroceptive touch, in which some external frame of reference is utilized, interoceptive space of bodily sensations is organized according to a somatotopic frame determined by relations between skin fragments and stable, structural organization of the body. However, it may still be asked whether such interoceptive space possesses the crucial characteristics of a spatial field.

This above differences intuitively shows that the exteroceptive space in which tactile objects are presented and the interoceptive space of tactile sensations are not the same and may have distinct properties. Later, I argue that only interoceptive space has the characteristic of a spatial field. It should be noted that I do not aim to identify interoceptive tactile space and exteroceptive tactile space with any particular representation postulated within psychological works (see Carruthers, 2008; Longo, 2016; Longo et al., 2015 for reviews). Instead, both the exteroceptive space of tactile objects and the interoceptive space of tactile sensations seem to rely on various types of information gathered by different types of receptors and stored in multiple bodily representations (see further sections for details).

3. Interoceptive tactile space as a spatial field

There is little doubt that tactile bodily sensations are presented as having certain spatial properties. For instance, they can be experienced as having a certain bodily location, size, and shape (Mattens, 2016; O'Shaughessy, 1989). Furthermore, tactile bodily sensations can mirror some of the spatial properties of touched objects. According to some authors (see Martin, 1992; Richardson, 2011), this feature allows tactile bodily sensations to mediate exteroceptive touch. Similarly, it is plausible to assume that we are presented with spatial relations between tactile bodily sensations. In particular, there are studies showing that tactile bodily sensations are experienced as positioned at some distance (see Haggard et al., 2017; Longo & Golubova, 2017) and in some direction from each other (see Haggard & Giovagnoli, 2011).[4]

One may doubt whether the ability to recognize relations between tactile sensations is a genuine perceptual phenomenon and does not result from post-perceptual judgments combining sensory information about bodily location of sensations with general knowledge about the structure and size of the body. I believe that there are three reasons why this option is less likely. First, researchers have identified various biases affecting assessments of spatial relations. For instance, the distance between tactile bodily sensations seems larger when each sensation is localized on a different body part separated by a joint (de Vignemont et al., 2009). However, it is not clear why such bias should occur in the case of a post-perceptual judgment, as our propositional knowledge about bodily structure does not suggest that joints somehow increase the distance between skin fragments. Second, in studies concerning interoceptive tactile spatial relations, stimuli are often applied in proximity, on the same body part (e.g., several centimeters from each other, see Mancini et al., 2014). Nevertheless, our post-perceptual knowledge about the body seems to be quite abstract such, that it contains information regarding the body parts that are connected and approximate distance between distinct body parts, but it does not seem to specify what is the distance between some unremarkable proximal skin fragments. Third, adaptation aftereffects concerning spatial relations between tactile sensations have been discovered and their presence suggests such spatial relations are computed at early stages of sensory processing relying on local, cutaneous data (see Calzolari et al., 2017).

[4] Nevertheless, this is not to deny that there are certain respects in which tactile bodily sensations can be characterized as non-spatial (see Matthen, 2021). For instance, a tactile sensation extending from groin to foot may not inform about the spatial relations between parts of a leg.

It is far more controversial whether tactile bodily sensations are presented in a space having the characteristics of a spatial field, i.e., whether that they are presented as located in topologically connected space whose fragments can be empty and whose structure remains the same no matter the relationship between the sensations experienced. For instance, Martin has argued against the presence of an interoceptive tactile field by stating that touch represents objects located outside bodily boundaries, and bodily space is not experienced as empty but as occupied by a particular object—the body itself (Martin, 1993). However, such a conviction seems to underestimate the interoceptive aspect of touch in virtue of which the body is not one of the presented objects, but rather, is the space in which bodily sensations are located.

Furthermore, Martin (1992) has proposed that tactile space is not a field because touch cannot, in opposition to vision, presents the space extending between experienced entities. In contrast, some authors claim that interoceptive bodily space has the form of a field, as there are tactile experiences in which one experiences not only spatial relations between sensations but also the empty space between them (see Ratcliffe, 2008; Mac Cumhaill, 2017; Scott, 2001 for various examples). For instance, it seems that when having an experience caused by a brush moved against the skin, one experiences not only pressure sensations caused by bristles, but also that there is no sensation between them. However, such examples do not show that the perceptual space of tactile bodily sensations is relation independent, i.e., that it is structurally the same no matter of the presented spatial relations between sensations. It is so because the examples provided concern cases in which one experiences empty tactile places given the presence of specific spatial arrangements of tactile sensations.

More recently, the idea of the interoceptive tactile field was argued for by referring to the notion of 'skin-space' and to experiments concerning the tactile path integration, i.e., an ability to recognize the middle spatial position between the start and end point of a tactile stimulation (see Cheng, 2019; Fardo et al., 2018; Haggard & Giovagnoli, 2011; Haggard et al., 2017). Skin-space is a low-level bodily representation whose structure is determined solely by the arrangement of the receptive fields of tactile receptors positioned on the skin's surface (see Cheng & Haggard, 2018, p. 61). It is postulated that skin-space allows the perception of spatial relations between tactile sensations as, for instance, distance between sensations can be computed relying on the number of receptive fields separating the points of tactile stimulation. Studies concerning skin-space are relevant for the investigations of the interoceptive tactile field, since participants in such studies are usually asked not to report the spatial structure of an external stimulus but the pattern of relations between sensations within a bodily framework.

However, these recent defenses of the interoceptive tactile field have three limitations. First, an intuitive understanding of the spatial field was used, without explicitly characterizing how the spatial field is different from other spatial representations. Second, the authors have focused on the fact that tactile perception is able to compute spatial relations between bodily sensations (Cheng, 2019, pp. 235-237; Cheng, 2020; Cheng & Haggard, 2018, pp. 62-63; Fardo et al., 2018, p. 101; Haggard & Giovagnoli, 2011). However, such a conclusion is too weak, as entities may be represented as standing in spatial relations without representing them as located within a spatial field. In particular, Martin, in his classic critiques of the notion of 'tactile field,' did not deny that touch is able to represent spatial relations. However, he believes the mere ability to represent spatial relations provides only an 'etiolated' concept of the spatial field (Martin, 1992, p. 208). Instead, he focused on the fact that tactile modality, differently than vision, does not represent space between spatially related items (see Martin, 1992, pp. 203, 205-208, and Martin, 1993 for an example of a climber who touches several points of a wall). Third, defenses relaying on the notion of 'skin-space' have mainly concerned the way in which tactile mechanisms process sensory information. However, even if sensory information is processed in the way characteristic for a spatial field, it does not automatically entail that the crucial spatial characteristics are presented in tactile experiences.

Below, I argue in three steps that interoceptive tactile space has characteristics of a spatial field. In the first step, I characterize selected bodily representations in virtue of which tactile sensations are presented as having a spatial localization. Subsequently, I show that the relevant bodily representations have features characteristic of spatial fields. Finally, I argue that these features are phenomenally presented in interoceptive tactile experiences. More specifically, I focus on two bodily representations: (a) skin-space, which represents the body relying on the layout of cutaneous receptors (e.g., Cheng & Haggard, 2018; Fardo et al., 2018) and (b) a stable, off-line body schema, which represents the body as a structure made of parts connected by joints (e.g., Hochstetter, 2016; Longo & Haggard, 2010; de Vignemont, 2010). I do not claim that these are the only representations which are relevant for presenting tactile bodily sensations as spatially located. In particular, a 'superficial schema' is proposed which is a representation whose function is to allow localization of tactile sensations on the skin's surface and so it seems to serve a similar role to that of skin-space (see Head & Holmes, 1911 for a classic source regarding superficial schema and Longo, 2016 for a contemporary review). However, because discussions concerning tactile field usually refer to the skin-space, I am focusing on this notion.

3.1 Skin-space and stable body schema

Intuitively, it seems that tactile bodily sensations are experienced as positioned at some places on the body's surface. For instance, we may simultaneously experience a tactile sensation on the forearm and on the arm above the elbow. This happens due to the functioning of bodily representations, which usually, but not always (as strikingly demonstrated by the example of phantom limbs), allow for sensations to be presented as positioned within the boundaries of the actual body. As noted above, one of such representations is skin-space which is determined by the array of tactile receptors covering the skin (Cheng & Haggard, 2018; Fardo et al., 2018). The information provided by the array of skin receptors allow, *inter alia*, recognition that some tactile sensations are closer to or further from each other depending on the amount of skin separating them (Haggard & Giovagnoli, 2011). These distances are established largely independent from the current position of body parts, as the layout of receptors between those which receive tactile stimulation remains the same no matter how the body is positioned. Earlier, when comparing interoceptive aspects of experiences Short and Long, I noted that there is a sense in which locations of tactile sensations remain the same no matter whether fingers are closer to or further from each. This important feature, characteristic for interoceptive tactile space, is likely to be at least partially provided by skin-space.

While skin-space, due to its high 'resolution' provided by the dense array of cutaneous receptors, may provide detailed information about the location of sensations on the skin and the distance between them, it does not allow, unless supplemented information from other representations, recognition of the body part in which a sensation occurs, and whether two sensations are located in the same body part (Cheng & Haggard, 2018; de Vignemont et al., 2006; de Vignemont, 2017). This is because skin-space provides information about arrangement of skin fragments, for instance that a fragment *A* is in distance *D* from a fragment *B*, but does not contain information whether, between *A* and *B*, a border between bodily parts is present. In consequence, additional information is required to recognize, for instance, that one sensation is below the elbow and second above it. In particular, due to the fact that the structure of interoceptive tactile space is independent from the current bodily posture, the major role in experiencing that a sensation in present in the particular body part seems to be played by the stable, off-line body schema (de Vignemont & Massin, 2013; de Vignemont, 2014). This bodily representation provide data about the general division of body into parts, for instance that hand is separated from forearm by wrist no matter whether wrist is bend or not. In case of the Short and Long experiences, the stable body schema allows representation of the fact that one tactile sensation is on the index finger, the second on the thumb, and that they are separated by a certain fragment of the hand.

It should be noted that the usage of terminology concerning bodily representations is not uniform across the literature. For instance, in some works the term ‘body image’ is also used to name a structural representation of a body (see O’Shaughessy, 1998). Hence, for the sake of clarity, I adopt a convention whereby ‘body schema’ means a representation which presents a body as a structure made of parts standing in spatial relations (Hochstetter, 2016; Longo & Haggard, 2010; de Vignemont, 2010). May authors introduce, in addition to the off-line body schema, a short-term or on-line body schema which represents the way body parts are positioned at a given moment (Carruthers, 2008; O’Shaughessy, 1989; Proske & Gandevia, 2012). It is also generally agreed that the information provided by both off-line and on-line body schemas are crucial in conducting bodily actions.

The fact that tactile bodily sensations are localized by using skin-space and the stable body schema already suggests that such sensations are presented as located in some space whose structure is determined by pattern of skin-receptors and the way in which body is divided into parts. However, it is not yet clear whether these bodily representations have properties which allow for presenting tactile bodily sensations as located in a space with the crucial characteristics of a spatial field.

3.2 Field-like characteristics of bodily representations

As proposed earlier, a perceptually presented space is a spatial field if and only if (a) it is topologically connected, (b) its structure is independent from the pattern of spatial relations between presented entities, and (c) it can contain empty locations.

Let's start from considering the first characteristic: topological connectedness. This feature is explicitly present in the case of skin-space, as it represents the body as relying on the pattern of receptors covering the skin (see Longo & Golubova, 2017 for a conceptualization in terms of a 2D array of pixels). In consequence, the body model provided by the skin-space has the form of a topologically connected surface such that each pair of locations is connected by some spatial path. The stable body schema also has properties that support presenting tactile bodily sensations within a topologically connected space. It is so because stable body schema models body as a structure of topologically connected parts. For instance, it represents that a finger is connected to a hand, a hand is connected to a forearm, etc., such that it provides information about a spatial path which leads from one body part to another (e.g., de Vignemont, 2017; de Vignemont et al., 2009).

The second characteristic of spatial fields, i.e. relation independence, is also supported by both of the representations considered. The topological structure of the skin-space is determined by the positions of skin receptors, and so stays the same no matter which receptors receive stimulation at a given moment and regardless of the spatial relations between stimulated receptors. Similarly, the structure of the stable bodily schema is determined by the way in which fragments of the body are connected by joints and is not influenced by the current pattern of tactile stimulation within bodily parts.

The situation is no different when the final characteristic of spatial field is considered: the possibility of empty locations. In particular, the structure of skin-space is determined by the array of receptors, no matter their current activities. Thus, the skin-space can model the body as a space containing places in which no tactile stimulation is present. Analogously, in the case of the stable body schema, the structure of body parts is represented no matter whether there is some tactile stimulation affecting these parts.

Nevertheless, even if the properties of skin-space and the stable body schema support characterizing interoceptive tactile space as a spatial field, one may still argue that these properties are not reflected within the structure of a conscious tactile experience. In particular, it is possible that by using bodily representations interoceptive tactile space is represented in a field-like way only on a subpersonal level. For instance, in considerations regarding the body schema, authors often mention that such bodily representation is only peripherally present in consciousness and is mainly used in navigating actions (see Elder, 2013; Hochstetter, 2016; Kinsbourne, 1995).

3.3 Spatial field and tactile experience

The doubt introduced above can be specified in two main ways. First, it can be postulated that the bodily space in which interoceptive tactile sensations are positioned is not perceptually experienced at all. Using a visual analogy, experiencing space between tactile bodily sensations is not like experiencing a part of visual field between two objects but like visually experiencing the space behind our head—there is simply no such experience. Second, one may claim that while interoceptive tactile space is perceptually presented, it is not presented as having the characteristics of a spatial field.

I believe that there are important reasons for refuting such worries. First, interoceptive tactile space seems to have boundaries. Our bodily representations present the body as a region in which tactile sensations may occur in opposition to regions, outside presented bodily boundaries, in which such sensations cannot be felt (see Martin, 1992; 1993). Thus, it is difficult to maintain that the bodily space of tactile sensations is not experienced at all, as it is at least experienced as a region of possible tactile sensations in opposition to other spatial regions.

Furthermore, there are psychological results suggesting that not only is interoceptive tactile space perceptually presented, but it is presented as having characteristics important for field-status. In particular, such reasons are provided by studies concerning tactile path integration (see Fardo et al., 2018). In these studies, a continuous, moving tactile stimulus is applied, such that a participant has a tactile sensation starting at one bodily point and moving towards a spatially separated bodily point along an S-shaped path. The task of participant is to point to the bodily location positioned midway between the starting and ending points. Due to the curved path of stimulus motion, this mid-point does not receive tactile stimulation.

While the locations chosen by the participants is not exactly the middle location between the starting and ending points, as the responses are biased toward the S-shaped path, the experiment demonstrates that people succeed in choosing a non-stimulated location lying in proximity to the mid-point. I believe that such results have important implications. While, of course, behavioral data do not provide any direct access to experiential phenomenology, it is plausible to assume that participants rely on the phenomenal character of their tactile experience in order to choose the proper bodily location. In consequence, the phenomenal character of an experience should be such that it allows participants to be quite successful in the path integration tasks. First, the results of the considered study suggest that people not only experience tactile bodily sensations as positioned in some spatial relationships, but also as separated by some continuous space. As a result, they do not merely refer to relative distance or direction between points, but can point out a bodily location between them.

Furthermore, the space between two points should be presented as topologically connected, because in order to identify a location close to the mid-point one has to recognize that there are spatial paths connecting locations of felt sensations. Second, because a location close to the mid-point can be identified while not being tacitly stimulated, it seems that one can experience an empty fragment of bodily space. Third, it does not seem that the changing relationship between sensations modifies the experienced topological structure of interoceptive tactile space. In particular, there are many distinct tactile paths—with greater or smaller curvature—which, despite differences in spatial characteristics, have the same mid-point between their starting and ending location. Nevertheless, the varying spatial relations between fragments of such paths do not prevent people from pointing to a location close to the same mid-point. It suggests that the experiential structure of space remains the same regardless of the changing relational characteristics.

Data from path integration studies are not the only evidence for the conclusions above. Another piece of evidence comes from the presence of interoceptive, spatial tactile attention (see Spence & Gallace, 2007 for a review). A person is able to focus attention on a bodily fragment in which no tactile sensation is felt, and in consequence, sensations which subsequently appear in the attended part are processed more efficiently. In addition, such attention is not only exogenous but also endogenous, i.e., a person may voluntarily choose the bodily fragment to which they attend. It is an analogous perceptual ability to the case of visual spatial attention, which can be focused not only on visible objects, but also on fragments of space (see Scholl, 2001).

The presence of tactile spatial attention, which is both interoceptive and endogenous, additionally suggests that the bodily space of tactile sensations is somehow experientially presented. In fact, if there were no experiences of interoceptive tactile space, we would be unable to endogenously focus attention on its fragments, just as we are unable to focus visual attention on locations outside the visual field. Furthermore, it is likely that, as a result of an attentional focus, some characteristics of bodily space are experientially presented, because attending to an element is usually associated with an occurrence of a phenomenal character presenting the properties of an attended thing (see Boxtel et al., 2010 for a review, in fact, some authors propose a stronger thesis that attention is necessary and sufficient for conscious experience, see Prinz, 2000). In particular, bodily fragments selected by tactile attention tend to be topologically connected; for instance, attention can be focused on one of the hands (e.g., Forster & Eimer, 2005). In addition, due to the endogenous aspect of tactile attention, it can be focused on bodily fragments free of any tactile sensations (e.g., Lakatos & Shepard, 1997). Furthermore, there is no evidence that the topological structure of attended fragments depends in any way on the relationship between perceived tactile sensations. It rather seems that endogenous tactile attention can select a bodily fragment, and then various patterns of sensations can be experienced as located within the structurally same fragment. Again, such properties suggest that the interoceptive bodily space is experientially presented as a spatial field.

An additional question is how to precisely characterize the relation between attention and experiential presence of the tactile field (or its fragments). A strong thesis that tactile field is experienced even pre-attentively may be proposed, but focusing attention makes its phenomenal presence more vivid and allows for more fine-grained spatial discriminations. However, a weaker thesis is also available stating that focusing attention is necessary for experiencing bodily space as a tactile field. Here, I do not attempt to determine the option that is more plausible, since both are coherent with the main thesis that interoceptive tactile space is experienced as having field-like characteristics.

Despite the behavioral evidence presented above, one may still argue that phenomenal character of interoceptive tactile space is so impoverished that we should refute the idea that such space is experienced as a spatial field. For instance, it is not clear that there is any positive experiential quality we feel in parts of interoceptive bodily space in which no tactile sensations are currently present. Furthermore, many locations within this space are not clearly separated by any experienced boundaries. Overall, a common conviction is that bodily space is only peripherally present in conscious experiences unless attention is focused on a bodily part or the functioning of bodily representations is somehow disrupted (e.g., Hochstetter, 2016).

However, such observations are also largely true about the phenomenal character of visually presented space. In particular, the empty space between visually presented objects or between objects and the observer does not have any vivid positive quality. Similarly, fragments of empty visual space are not clearly differentiated from each other by some experiential borders. Furthermore, a common intuition concerning the transparency of visual experiences suggests that what is phenomenally presented in such experiences are external objects and the surrounding space has a much weaker phenomenal presence (e.g., Martin, 2002). Thus, the phenomenology of visually presented space is sometimes characterized as "see-through" phenomenology, to indicate that visually presented locations are not as phenomenally salient as visually presented objects (see Mac Cumhaill, 2015). These similarities between the phenomenal character of visual space, which is commonly characterized as a spatial field, and interoceptive tactile space suggest that the peripheral phenomenal character of interoceptive bodily space is not a strong reason to deny it the status of a spatial field. Quite the contrary; such phenomenal character may be typical of perceptually presented empty space.

The considerations outlined above show that tactile bodily sensations are presented as located due to the functioning of bodily representations that possess characteristics crucial for field-status. Furthermore, there are data suggesting that these crucial characteristics are reflected in the conscious, interoceptive tactile experiences. Thus, it is plausible to accept that tactile bodily sensations are experienced as located in a spatial field.

4. Exteroceptive tactile space

While there are strong reasons for characterizing interoceptive tactile space as a spatial field, the same is not true of exteroceptive tactile space. Exteroceptive space is not the bodily space in which tactile sensations are experienced, but one in which external tactile items are presented to be located. For instance, in our example concerning experiences Short and Long, the tactile sensations on fingers are experienced as located within interoceptive bodily space but the held stick is experienced as located outside bodily boundaries, between the fingers. Below, I consider the major ideas present in empirical literature concerning the mechanisms involved in the perception of exteroceptive tactile space, and I argue that the way in which external tactile objects are spatially presented does not support the interpretation of exteroceptive tactile space as a spatial field.

The tactile perception of external objects is mainly achieved through haptics, i.e., by active exploration of the environment by using the hands, a process which provides both cutaneous and kinesthetic information (Fulkerson, 2014; Klatzky & Lederman, 2004). Cutaneous data are provided by the skin receptors, which are affected by the external objects. Thus, exteroceptive touch partially relies on the same representations as interoceptive touch (see Cheng, 2019). For instance, a bodily representation such as skin-space may be helpful in determining where external objects are touching the body. Kinesthetic information concerns the current positions of bodily parts and allow determination—as in experiences Short and Long—of the size of touched items, and of their other spatial properties such as volume, shape or pattern of contours (Fulkerson, 2011; Lederman & Klatzky, 2009). In consequence, unlike the case of interoceptive touch, exteroceptive touch relies more heavily not on a stable body schema, but on the on-line body schema representing the actual positions of body parts (Carruthers, 2008; O'Shaughnessy, 1998; de Vignemont, 2014; de Vignemont et al., 2006). In particular, information about the spatial properties of external objects is mainly obtained by relying on current relations between hands and fingers and not on the stable topological relations between bodily fragments. In fact, there is a variety of empirical studies demonstrating abilities in perceiving spatial properties and relations in virtue of haptics. For instance, haptic information allows recognizing distance between surfaces (Gepsthein & Banks, 2003), perceiving curvature (van der Horst et al., 2008), drawing shapes in empty space using hand movements (Vivani et al., 1997), and grasping objects without help from vision (Baud-Bovy & Vivani, 1998; Darling & Miller, 1993). Various diachronic patterns of movements by which exteroceptive cutaneous and kinesthetic information is gathered are known as exploratory procedures. Psychological investigations have established that different exploratory procedures are suited for gaining information about certain properties (Klatzky & Lederman, 2004). For instance, enclosing an object in a hand provides data about its volume and general shape, while tracking contours using a finger allows recognition of details of its boundaries.

Haptics, by using cutaneous and kinesthetic information, allows the representation of external objects as instantiating a variety of tactile properties. Nevertheless, it is still a question whether haptically represented objects are represented as positioned in a spatial field. Below, I consider three ways in which one may attempt to justify that there is a spatial field containing external tactile object. First, it may be proposed that cutaneous information is sufficient to present tactile objects as positioned in an exteroceptive tactile field. Second, I consider whether this result can be obtained by using both cutaneous and kinesthetic data. Third, one may claim that the thesis concerning the presence of an exteroceptive spatial field can be justified by referring to the notion of peripersonal space. I argue that none of these options provides a sufficient support for the idea of exteroceptive tactile field.

4.1 Cutaneous information and exteroceptive space

Let's start by considering the way in which cutaneous information can contribute to representing exteroceptive tactile space. As an example, we can consider an experience caused by pressing a ring-shaped object to the skin. Such an experience is not solely an interoceptive tactile sensation but is also an exteroceptive experience, presenting that there is something in the space outside the body. By obtaining cutaneous data, and by utilizing the fact that properties of tactile bodily sensations can reflect the properties of external objects (Martin, 1992; Richardson, 2011), tactile perception may represent the item touching the skin as a common subject of various spatial properties such as shape and size. Furthermore, it seems that by detecting a lack of stimulation beyond the outer and inner boundaries of the ring, the exteroceptive touch may represent that some fragments of external space are empty, as there is no stimulation from some regions proximal to the skin's surface. However, processing cutaneous data does not provide information about the topological structure of external space in which the tactile objects are positioned. In particular, data gathered by skin receptors allow recognition of the arrangement of surfaces influencing the body but do not convey information regarding how the space extending beyond the bodily boundaries is organized. In the case of interoceptive tactile space, its topological structure was, in important respects, determined by the array of skin-receptors. Nevertheless, when applied to exteroceptive space, information obtained by skin-receptors is not sufficient for determining its topological structure, as the structure of exteroceptive space is not a bodily structure, but the structure of space outside the body.

4.2 Kinesthetic information and exteroceptive space

Of course, in usual situations the exteroceptive tactile perception utilizes not only static cutaneous data but also relies on kinesthetic data and engages in dynamic exploratory procedures. Thus, one may believe that in virtue of these complex, dynamic operations exteroceptive tactile space is presented as a spatial field. However, while by relying on kinesthetic information one may successfully grab objects without use of vision (Baud-Bovy & Vivani, 1998; Darling & Miller, 1993) or one can perceive spatial relationships between external object (Gepsthein & Banks, 2003), it seems that to account for such abilities it is enough to postulate some form of relational, egocentric or allocentric, spatial framework, and a reference to a genuine spatial field is not needed. For instance, grasping an object requires representing egocentric relations between an object and the body, as well as the various spatial relations between bodily parts needed for successful conduct of a proper movement. Similarly, to haptically assess distances between surfaces, a perceptual system needs to represent relations between body parts touching the considered surfaces. In both cases, there is no justification for introducing a topologically connected spatial field in addition to relational representations.

However, one may argue that haptic exploratory procedures may, in fact, allow for representing space as having features typical for spatial fields. For instance, by processing both cutaneous and kinesthetic information, in experiences such as Short or Long we are presented not only with some surfaces exerting pressure on the skin, but with an object extending in external space from one finger to another. In consequence, it seems that such experiences present a topologically connected, external spatial path between fingers. Similarly, when grabbing an item we may perceive that a fragment of the external space is empty, since the moving limb is meeting no resistance and that the fragment of space is topologically connected as a body part moves towards an item along a continuous path.

Nevertheless, while such examples may justify that by combining cutaneous and kinesthetic information external space is represented as topologically connected and empty, the second characteristic of spatial fields, relation independence, is not fulfilled. According to this characteristic, the topological structure of a spatial field remains the same despite changes in relational arrangements of elements presented with this space. However, in the case of haptic experiences using kinesthetic information, the presented structure of space supervenes on presenting particular relations between tactile objects and body parts. In other words, distinct haptic experiences can present space as having a distinct structure, such that this structure is determined by the presented relational pattern.

For instance, when one grabs an object, a certain pattern of spatial relations between bodily parts is presented, and the occurrence of such patterns allows a certain continuous, empty spatial path *P* leading to an object to be presented. Nevertheless, if the object were to be grasped by a different bodily movement, a distinct spatial path *P'* would be presented, determined by an alternative pattern of spatial relations. Similarly, if no grasping attempt was conducted, neither *P* nor *P'* would be presented, as there would be no kinesthetic information regarding the space between the body and the object. In contrast to vision and interoceptive touch, there are no mechanisms which would allow the structure of space to be presented in a way that is unaffected by the occurrence of spatial relations concerning bodily parts and external objects. Hence, even when cutaneous information is combined with kinesthetic information, exteroceptive space of tactile objects does not have the character of a spatial field, as its presented topological structure is not independent of presented relations between objects and bodily parts.

4.3 Peripersonal space

The space close to the bodily boundaries is likely to be represented in a distinct way in contrast to farther space (Holmes & Spence, 2004; Longo & Laurenco, 2006; Makin et al. 2007). In particular, it has been established that there are multimodal neurons, activated by both visual and tactile stimuli, which are responsible for coding the presence of objects in the vicinity of the body (Cardinali et al., 2009; Fogassi et al., 1996; Ladavas, 2002). It may be proposed that such 'peripersonal space' is an exteroceptive spatial field in which tactile objects are presented to be located. For instance, distinct multimodal visuo-tactile neurons may code distinct fragments of the peripersonal space, such that as a result a topologically connected space around the body is represented. In consequence, the structure of the peripersonal space would be analogous to the structure skin-space with an exception that it is not restricted to a bodily surface but encompasses regions around body parts.

In fact, there is an obvious sense in which objects presented in peripersonal space are presented as located in a spatial field. If peripersonal space is a multimodal visuo-tactile space, then objects presented as located in such a space are visually located in a fragment of the visual field. However, such an answer trivializes the question regarding the exteroceptive tactile field. It is obvious that for many objects it is possible to simultaneously touch and see them and so experience them as positioned within a spatial field. Nevertheless, in such cases the characteristics crucial for spatial fields are provided solely by the visual modality and so it is not justified to claim that experiences of joint touching and seeing an object provide reasons to postulate the presence of an exteroceptive tactile field.

However, it may be claimed that peripersonal space is a genuinely tactile space which is shaped due to interactions with visual modality such that, at some stage of ontogenetic development, it acquires the characteristics of a spatial field. In this case the field-like characteristics would depend on visual modality only in a causal sense. Without vision, peripersonal space cannot acquire features of a spatial field, but after such acquisition, visual input is no longer necessary, and a peripersonal spatial field is present due to the activities of tactile mechanisms. In fact, the presence of visual influences which modify tactile spatial representations is not implausible. For instance, it has been proposed that vision provides interoceptive bodily space with information regarding the size of bodily parts (de Vignemont, 2014), and there are results suggesting that sighted people have greater tactile recognition of orientation-related properties, even when visual input is blocked (Gori et al., 2010).

Nevertheless, the main models of peripersonal space do not support this hypothesis as they suggest that peripersonal space is a relational space presenting objects as standing in egocentric relations to body parts, and not as positioned in a topologically connected spatial field. In particular, multimodal neurons coding peripersonal space are activated by changes in the distance of objects from the body and their velocity (Holmes & Spence, 2004; Fogassi et al., 1996). Hence, peripersonal space is usually characterized in terms of a relational, somatocentric reference frame in which objects are represented as positioned at some distance from a specific body part (Cardinali et al., 2009). Even if peripersonal space is sometimes described as a 'field,' it is not characterized as a spatial field, but as a field specifying relevance of actions aiming to create or avoid contact with the body (see Bufacchi and Iannetti, 2018). Explaining the ability to perform such actions may require complex representations utilizing egocentric frames of reference to be postulated (see Alsmith, 2017), but they do not make it necessary to assume the presence of a field-like tactile space.

5. Conclusions

Answering the question concerning the presence of tactile field requires distinguishing two forms of tactilely presented space: interoceptive space, in which tactile bodily sensations are experienced as located, and exteroceptive space, in which external tactile objects are presented. I have argued that while interoceptive tactile space is presented as a spatial field, the same is not true of exteroceptive tactile space. Due to the functioning of bodily representations such as skin-space and the stable body schema, the interoceptive tactile space is presented as having crucial characteristics of spatial fields: it is topologically connected, relation independent, and it can contain empty places. It is not plausible to ascribe these characteristics to the exteroceptive tactile space. In particular, the exteroceptive tactile space is not relation independent: the way in which its topological structure is presented changes as a result of modifying spatial relations between experienced tactile objects and body parts.

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