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## Peripersonal perception in action

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Abstract	Philosophy of perception is guilty of focusing on the perception of far space, neglecting the possibility that the perception of the space immediately surrounding the body, which is known as peripersonal space, displays different properties. Peripersonal space is the space in which the world is literally at hand for interaction. It is also the space in which the world can become threatening and dangerous, requiring protective behaviours. Recent research in cognitive neuroscience has yielded a vast array of discoveries on the multisensory and sensorimotor specificities of the processing of peripersonal space. Yet very little has been done on their philosophical implications. Here I will raise the following question: in what manner does the visual experience of a big rock close to my foot differ from the visual experience of the moon in the sky?
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# Peripersonal perception in action

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## Abstract

Philosophy of perception is guilty of focusing on the perception of far space, neglecting the possibility that the perception of the space immediately surrounding the body, which is known as peripersonal space, displays different properties. Peripersonal space is the space in which the world is literally at hand for interaction. It is also the space in which the world can become threatening and dangerous, requiring protective behaviours. Recent research in cognitive neuroscience has yielded a vast array of discoveries on the multisensory and sensorimotor specificities of the processing of peripersonal space. Yet very little has been done on their philosophical implications. Here I will raise the following question: in what manner does the visual experience of a big rock close to my foot differ from the visual experience of the moon in the sky?

**Keywords** Peripersonal · Perception · Space · Body · Action · Pain · Affordance · Egocentric · Threat

Philosophy of perception has often been accused to analyse perception exclusively on the model of vision, but it is also frequently guilty of focusing on the perception of far space, neglecting the possibility that the perception of the space immediately surrounding the body, which is known as *peripersonal space*, displays different properties.<sup>1</sup> This neglect may be easily understandable insofar as we seem to be presented with a continuous visual field devoid of phenomenological boundary between what is close and what is far. Standard accounts of perception acknowledge the importance of the spatial relation between the subject and the perceived object by ascribing egocentric content to perceptual experiences, but the spatial relation is primarily spelled out in terms of direction (left, right, up and down, for instance), and not in terms of proximity. Yet recent research in cognitive neuroscience has yielded a vast array of discoveries on the multisensory and sensorimotor specificities of the processing of

<sup>1</sup> For exception, see for instance Ferretti (2016).

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26 peripersonal space. Here I will draw the philosophical implications of these findings  
 27 and raise the following question: does seeing a big rock close to my foot differ from  
 28 seeing the moon in the sky? As a first approximate answer, we can note the following:  
 29 I can touch and manipulate the rock, but not the moon; I need to be able to immedi-  
 30 ately move away if the rock rolls towards me or to go around it if I am walking. More  
 31 generally, peripersonal space is the space in which the world is literally at hand for  
 32 interaction. It is also the space of immediate danger, requiring protective behaviours.  
 33 It thus appears that whatever is perceived in peripersonal space is relevant for action.  
 34 But how to characterize in details this relation to action? And is it specific to the  
 35 perception of peripersonal space or can it also be true of the perception of far space?  
 36 One may indeed reply that what is significant for the subject is not restricted to the  
 37 space that immediately surrounds her. Seeing a lion thirty meters away has clearly an  
 38 impact on my behaviour and I should not wait to react for the lion to be next to my  
 39 body, when it is actually too late. In what sense, then, is the perception of peripersonal  
 40 space unique?

## 41 1 Peripersonal perception

42 The hypothesis that there is something specific about the way we perceive the space  
 43 surrounding our body has first appeared in ethology and in social psychology (Hediger  
 44 1950; Hall 1966). The boundaries of this spatial area are then defined exclusively in  
 45 social terms and vary depending on the type of social interactions. As noted by the  
 46 social psychologist Hall (1966, p. 10): “Each animal is surrounded by a series of  
 47 bubbles or irregularly shaped balloons that serve to maintain proper spacing between  
 48 individuals.” He then distinguishes between the intimate space, in which we can feel  
 49 the warmth of another person’s body (up to 45 cm), the personal space, in which we can  
 50 directly interact with the other (up to 1.2 m), the social space, in which we can work or  
 51 meet together (up to 3.6 m), and the public space, in which we have no involvement with  
 52 other people. Since then, others have proposed to differentiate the various “bubbles”  
 53 by considering the different types of action that they enable. For instance, Cutting  
 54 and Vishton (1995) distinguish between what they call the personal space, also known  
 55 as the reaching space (Bartolo et al. 2014), the action space, in which we can move  
 56 quickly and throw projectiles, and the vista space, which is beyond 30 meters. Although  
 57 of great interest, most of these notions remain purely descriptive and there is a risk  
 58 of infinite multiplications of these bubbles. It then seems more interesting to turn to  
 59 cognitive neuroscience to determine whether the brain processes in any specific way  
 60 the space close to us. As we shall see, numerous studies in monkeys and humans, both  
 61 in healthy and pathological conditions, have found sensory and motor specificities of  
 62 peripersonal space (for review see Brozzoli et al. 2012). We may then propose that  
 63 there is such a thing, which we can call *peripersonal perception*, and which can be  
 64 defined for now as the perception of the space close to the body. It consists neither  
 65 in the perception of one’s own body nor in the perception of far space, but stands in  
 66 between.

67 **1.1 A multisensory signature**

68 The first study was done on monkeys by Rizzolatti et al. (1981), who recorded the  
 69 activity of neurons in the ventral premotor areas. They found that some were activated  
 70 not only by tactile stimuli on the body, but also by visual stimuli presented in the space  
 71 close to the body. They coined the term “peripersonal space” to refer to this spatial  
 72 area, which extends from a few centimetres from the body to approximately 30 cm.<sup>2</sup>  
 73 At the neural level, the proximity to the body is thus interpreted in a relatively narrow  
 74 way: it corresponds only to the immediate surrounding. □

75 Since Rizzolatti and his colleagues’ discovery of bimodal neurons, the main mea-  
 76 sure of peripersonal space has been the effect of visual and auditory perception on  
 77 tactile perception. This multisensory signature of peripersonal perception is well illus-  
 78 trated by the cross-modal congruency effect. Participants are asked to perform a rapid  
 79 discrimination of the location of a vibro-tactile stimulus presented either on the left or  
 80 on the right index finger or thumb, while trying to ignore visual distractors presented  
 81 simultaneously at either congruent or incongruent positions. Crucially, incongruent  
 82 visual distractors interfere with tactile discrimination (i.e. participants are both slower  
 83 and less accurate), but only when visual stimuli are close to the body (Spence et al.  
 84 2004).<sup>3</sup> A similar multisensory effect can be found in the neuropsychological syn-  
 85 drome of tactile extinction after right-hemisphere lesions. These patients have no  
 86 difficulty in processing an isolated tactile stimulus on their left hand but they are no  
 87 longer aware of the touch when they are simultaneously touched on their right hand  
 88 or crucially, when they see a visual stimulus *near* their right hand (Di Pellegrino et al.  
 89 1997).

90 Cross-modal effects are largely spread in perception in general but there is a notable  
 91 difference here. Consider the famous McGurk effect: when the auditory stimulus/aba/is  
 92 heard while looking at lips making movements that would produce the/aga/sound, one  
 93 reports hearing/ada/. In this example, the auditory signal and the visual signal are  
 94 assigned to the same source and they both carry verbal information. Their redundancy  
 95 increases the robustness and reliability of the perceptual judgment based on their  
 96 integration. The situation, however, is different in the cross-modal congruency effect.  
 97 The flash of light is a distractor that has nothing to do with the small vibrator on  
 98 the finger. Nonetheless, there is interaction because it is of interest for the perceptual  
 99 system *to predict* what will happen soon in order to improve the processing of the  
 100 forthcoming event (Engel et al. 2001; Hyvärinen and Poranen 1974). Specifically, the  
 101 sight of objects close to one’s body generates expectation of a tactile event, which  
 102 then influences the experience of the actual tactile stimulus. The perceptual system  
 103 generates such a prediction because it expects either the body to move toward the  
 104 object or the object to move toward the body. The predictive mechanism requires the  
 105 location of objects and events close to the body to be encoded relative to the location

<sup>2</sup> For instance, Rizzolatti and coll. found that half of the bimodal neurons responded only when the visual stimulus was within 10 cm of the body surface while the rest fired mainly when the visual stimulus was within reach of the arm. Graziano and Cooke (2006), on the other hand, describe that half of the neurons gives a strong response only when the visual stimulus is within 5 cm of the body surface; and most of the rest give a response when the visual stimulus is within 20 cm of the body surface.

<sup>3</sup> Similar multisensory effects have been found with auditory stimuli (Canzoneri et al. 2012).

of the various parts of the body, in what we may call bodily coordinates (or what others call somatotopic coordinates or skin-based coordinates), despite the fact that they occur in external space, that is, beyond the boundaries of the body.

Here it is important to clearly distinguish the bodily frame of reference from the egocentric one.<sup>4</sup> They are both body-part centred but their bodily centres play different roles. Bodily coordinates are typically used in the tactile modality: the location of pressure is encoded as occurring at a specific spot in the surface of the body. Egocentric coordinates are typically used by vision and audition: the location of the object is encoded as occurring at a specific point relative to some axes (left, right, above, below) centred on some key parts of the body (such as the head or the torso). What is interesting is that within peripersonal space, vision can also use bodily coordinates, which do not necessarily coincide with the egocentric ones. Consider the following example. There is a ladybug on my right next to my right hand. The egocentric content of my visual experience is given relative to the posture of my head and of my torso and if I cross my hands, my visual experience stays the same: it still presents the ladybug on my right. By contrast, the bodily coordinates of the ladybug have changed: it was in my peri-right hand and it is now in my peri-left hand. Now imagine that the ladybug follows my right hand. Then the egocentric coordinates of my visual experience change (on my left), but not its bodily coordinates (in my peri-right hand).<sup>5</sup> When a body part moves, what is perceived as occurring in its corresponding peri-space (such as the peri-head, the peri-torso, the peri-hand, and the peri-foot space) follows. As described by Graziano and Gross (1993, p. 107):

The visual space near the animal is represented as if it were a gelatinous medium surrounding the body, that deforms in a topology-preserving fashion whenever the head rotates or the limbs move. Such a map gives the location of the visual stimulus with respect to the body surface, in somatotopic coordinates.

From now on, I shall use this specificity of peripersonal space as its primary marker and offer the following working definition of peripersonal perception: peripersonal perception is the perception of objects and events that are localized in bodily coordinates despite being situated beyond the apparent boundaries of the body.<sup>6</sup>

<sup>4</sup> It should be noted that there are more than one definition of the egocentric frame. For some, for instance, the egocentric space is simply the action space (Evans 1985; Briscoe 2009; Ferretti 2016; Smith 2009). On this view, one may then claim that peripersonal perception is encoded in egocentric coordinates. However, by using such a wide definition, one risks losing part of the spatial specificity of peripersonal perception.

<sup>5</sup> The distinction is well illustrated in the cross-modal congruency effect. We just saw that when the hands are uncrossed, visual stimuli close to the left hand presented on the left side of the body affect tactile processing on the left hand. What happens when the hands are crossed? Then visual stimuli presented at the same egocentric location (on the left) but now close to the right hand affect tactile processing on the right hand. What matters is bodily location (left hand vs. right hand), and not egocentric location (on the left vs. on the right).

<sup>6</sup> Two points are worth noting here. First, the definition does not assume that objects and events are encoded *exclusively* in bodily coordinates. Arguably, they are also encoded in egocentric coordinates. Secondly, by apparent bodily boundaries, I mean the boundaries of the body as they are mentally represented. For instance, amputees represent the space that surrounds their phantom limb as peripersonal but the phantom itself is not part of peripersonal space, it is part of their apparent bodily space.

136 **1.2 Shortsighted vision**

137 Most discussions on peripersonal space have focused on multisensory perception but  
138 what about *unimodal* perception? Is the only peculiarity of peripersonal vision its effect  
139 on touch? Or is it also characterized by specific visual capacities? We know that close  
140 objects are easier to detect and discriminate but is it simply because they are seen as  
141 bigger or is it because they are seen in peripersonal space? Recent experiments indicate  
142 that our perceptual abilities are different in close and in far space, independently of  
143 the perceived size.<sup>7</sup>

144 The first main effect is that object detection is improved: participants make fewer  
145 errors and are faster in judging of the appearance of a visual stimulus in close space  
146 (Dufour and Touzalin 2008; Reed et al. 2006). One may be tempted to explain this  
147 advantage in attentional terms. Reed et al. (2010) propose that peripersonal space is  
148 given an automatic attentional priority. There is no need to have additional cues to tell  
149 the perceptual system to attend to this spatial area; proximity is the cue. Such a priority  
150 can be easily explained by the fact that whatever occurs in this space has immediate  
151 implications for the subject, whether it is to grasp it or to avoid it. Immediacy here  
152 should be understood both spatially and temporally. There is indeed an emergency  
153 attached to it: one cannot wait to process the information. Since more resources are  
154 allocated, processing can be more efficient.

155 However, one may reply that we should pay less attention to what is close because  
156 it is *most* likely that we have seen it before when it was still in far space. If so,  
157 there is proximity but there is no novelty. Furthermore, if attention were increased  
158 in peripersonal space, then one should be better in all perceptual tasks and this is  
159 not the case. Peripersonal perception appears sometimes to be less efficient than the  
160 perception of far space. For instance, when participants are asked to localize a target  
161 among distractors, they are slower when the visual display is close than when it is far  
162 (Abrams et al. 2008). How can participants be bad at finding a target that is just under  
163 their nose? Since they are supposed to pay more attention to this area, they should be  
164 able to locate the target immediately but they do not. How is that possible? What this  
165 reveals is that perception must be especially thorough in peripersonal space (Abrams  
166 et al. 2008). One can afford not looking at all the objects for a far away visual scene  
167 but partial overlook may be dangerous when it is next to one's body. In a nutshell,  
168 you need to watch closely where you put your foot while walking in the Amazonian  
169 forest: a brief scan of the leaves does not suffice; you need to make sure that there is  
170 no hidden snake. In other words, better safe than sorry, no matter the cost.

171 What about object discrimination? The results there are also contrastive (see Good-  
172 hew et al. 2015 for review). In a nutshell, the processing of temporal and spatial  
173 properties is facilitated, whereas the processing of colour information and of fine-  
174 grained properties is impaired (Gozli et al. 2012; Kelly and Brockmole 2014). Even  
175 within the perception of spatial properties in peripersonal space, one can distinguish  
176 between global features, such as orientation and shape, that are better discriminated  
177 (Blini et al. in press; Kelly and Brockmole 2014), and local features, such as a small

<sup>7</sup> The studies also control for the impact of other potential confounds. In brief, the effects cannot be explained by a higher visibility close to the hand, by the fact that participants give manual replies, or by the fact that viewing the hand attracts attention.



178 gap in a circle, that are more difficult to process (Gozli et al. 2012). This pattern of  
179 results may be partly explained by the hypothesis that peripersonal perception relies  
180 more on the dorsal stream of visual processing, which is involved in the guidance of  
181 basic actions, whereas the perception of far space relies more on the ventral stream  
182 dedicated to object identification (Milner and Goodale 2008). In particular, periper-  
183 sonal perception may involve a specific type of magnocellular neurons, M-cells, which  
184 are sensitive to quick changes and motion and which have large receptive fields so  
185 that they can process the overall gist of a scene although they have poor spatial acuity  
186 (Goodhew et al. 2015). Interestingly, recent evidence shows that the dorsal stream also  
187 participates in object recognition (Freud et al. 2017).<sup>8</sup>

188 To summarize, peripersonal perception is not governed by the same computational  
189 principles as the perception of far space and its main peculiarities seem to be the  
190 direct consequence of its link with action. On the one hand, multisensory effects result  
191 from the anticipation of the contact with the perceived object, a contact that may  
192 follow one's movements (when grasping an object, for instance), or that may cause  
193 one to react (by avoiding an approaching bee). On the other hand, visual effects result  
194 from the significance of what is seen for planning one's actions, whether to interact  
195 with what is seen or to withdraw from it. If this is the right analysis of peripersonal  
196 perception, then one can make the following prediction: the alteration of one's motor  
197 capacities should have an impact on peripersonal perception. We shall now see that  
198 this prediction is confirmed.

### 199 1.3 What one perceives depends on what one can do

200 I shall now show that the extent to which objects and events are processed in the  
201 way that characterizes peripersonal perception is partly determined by the practical  
202 knowledge of one's actual motor capacities. In brief, peripersonal perception covers a  
203 smaller space when one can do less and a larger space when one can do more. Consider  
204 first the case of tool use. One can act on farther objects with a tool than without. This  
205 increased motor ability leads to a modification of perceptual processing of the objects  
206 that are next to the tool. Before tool use, they are processed as being in far space;  
207 during tool use they are processed as being peripersonal. This was first described by  
208 a seminal study by Iriki et al. (1996) who trained monkeys to use a rake to reach food  
209 placed too far to be reached without the tool. They found that visuo-tactile neurons,  
210 which displayed no visual response to food at this far location before training, began  
211 to display visual responses after training. A few minutes after tool use was interrupted,  
212 the visual receptive fields shrank back to their original size. Likewise, when amputees  
213 wear their functional prosthetic arm, their peripersonal perception stretches farther:  
214 the distance at which an auditory stimulus is able to affect the processing of a tactile  
215 stimulus applied on the stump is farther away from it than before (Canzoneri et al.  
216 2013). Consider now cases in which the motor abilities are reduced. It has been shown  
217 that after 10 h of right arm immobilization there is a contraction of peripersonal space  
218 such that the distance at which an auditory stimulus was able to affect the processing of

<sup>8</sup> For further discussion on the interaction between the ventral and the dorsal stream, see Briscoe (2009), Briscoe and Schwenkler (2015), and Matthen (2005).

219 a tactile stimulus was closer to the body than before (Bassolino et al. 2015). Along the  
220 same lines, it has been found that in participants who wear wrist weights peripersonal  
221 perception is narrower (Lourenco and Longo 2009).<sup>9</sup>

222 These studies reveal two interesting properties of peripersonal perception. First,  
223 the influence of motor capacities is *online*. The tool is just used a couple of minutes  
224 but this suffices to affect peripersonal perception and a few minutes after the tool is  
225 dropped, the effect stops. Peripersonal perception is constantly updated, determined  
226 at each instant by what one can do. These studies also reveal one mechanism that  
227 explains the strong malleability of peripersonal perception. Tools and prostheses have  
228 been shown to be integrated into the *body schema*, which consists in a sensorimotor  
229 representation of the body that is used to guide action (e.g., Cardinali et al. 2009;  
230 Canzoneri et al. 2013). Increasing (or diminishing) one's motor abilities affects the  
231 body schema, which in turn affects peripersonal perception. Peripersonal perception  
232 is thus directly influenced by the body schema. The practical knowledge of one's  
233 "here and now" motor abilities determines whether objects and events are processed  
234 as being peripersonal or not. This reinforces the hypothesis that there is a special link  
235 between peripersonal perception and action. We shall now specify in more detail this  
236 relationship.

## 237 **2 The space within which the body acts**

238 No matter how complex actions can be and how many sub-goals they can have, all  
239 bodily movements unfold in peripersonal space. While walking, the step is made  
240 in the peripersonal space of my foot and while I move forward, this peripersonal  
241 space follows. Actions are performed by a segment of the body within the space that  
242 immediately surrounds it. Their guidance thus depends on the constant fine-grained  
243 monitoring and remapping of peripersonal space while the movement is performed. It  
244 is then no surprise that when Rizzolatti et al. (1981) found for the first time bimodal  
245 neurons that encode peripersonal space, they interpreted their function in motor terms:

246 The discharge of neurons reflects a potential action, a motor schema, directed  
247 toward a particular spatial location (motor space). The presentation of a visual  
248 stimulus or the memory of its location, as in the new study, would evoke auto-  
249 matically one of these schemata, which, regardless of whether it is executed,  
250 maps the stimulus position in motor terms (...) movements progressively carve  
251 out a working space from undifferentiated visual information. (Rizzolatti et al.  
252 1997, p. 191)

253 Peripersonal space is mainly represented in brain regions that are dedicated to action  
254 guidance (in the premotor areas and in the ventral section of the intraparietal sulcus).  
255 But how should one interpret this neuroscientific fact? What is the relation between  
256 peripersonal perception and action?

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<sup>9</sup> Lourenco and Longo (2009) assess the extent of peripersonal space by measuring a specific visual bias found only in peripersonal perception. When bisecting horizontal lines close to the body, individuals show a slight leftward bias, which shifts rightward when the line is presented in far space (Longo and Lourenco 2006). They found that individuals wearing wrist weights showed a less gradual rightward shift in the bias.

## 257 2.1 Neither too tight nor too loose

258 In the last section we saw that action determines peripersonal perception, to some  
 259 extent at least. The question that we have now is in what manner peripersonal percep-  
 260 tion determines action. Their relationship can take more or less extreme forms. Let  
 261 us, for instance, consider what Clark (2001) calls the assumption of experience-based  
 262 control,<sup>10</sup> which can be phrased as follows:

263       Conscious visual experience presents the world to the subject in a form appro-  
 264       priate for the control and guidance of fine-tuned, real world activity.

265 Even applied only to peripersonal perception only, and not to perception in general,  
 266 this assumption seems to be too extreme in light of empirical dissociations between  
 267 perception and action (Milner and Goodale 1995). One of the most recurrent empirical  
 268 arguments against the role of perception for action comes from the neuropsychological  
 269 dissociations between optic ataxia and visual agnosia. For example, the visual agnostic  
 270 patient DF was presented with a set of various squares and rectangles. She was at  
 271 chance when required to match the width of such simple geometrical forms but she  
 272 was accurately able to grasp the blocks. The reverse pattern of performance was found  
 273 in optic ataxic patients. The conclusion drawn from this double dissociation is that  
 274 one can have visual experiences of an object without being able to act towards this  
 275 object, and vice versa. Furthermore, it was repeatedly found in healthy individuals that  
 276 action could be immune to visual illusions. For example, in the Hollow Face illusion,  
 277 a concave (or hollow) mask of a face appears as a normal convex (or protruding)  
 278 face, but if asked to quickly flick a magnet off the nose (as if it were a small insect),  
 279 participants directed their finger movements to the actual location of the nose in the  
 280 hollow face, which was 8 in. away from the location at which the nose appeared to  
 281 be. In other words, the content of the visual experience of the face did not correspond  
 282 to the visually-guided movements directed toward the face (Króliczak et al. 2006).  
 283 This was taken as evidence in favour of the general model of vision according to  
 284 which we have two functional streams of processing of visual information, the dorsal  
 285 stream for visuomotor transformation and the ventral stream for visual awareness  
 286 (Milner and Goodale 1995). What is interesting for the purpose of our discussion on  
 287 peripersonal perception is that this dissociation occurred in peripersonal space: the face  
 288 was displayed at less than 30 cm from the participants. Hence, even in the space close to  
 289 us, the content of visual experiences (e.g., convex face) does not guide action-oriented  
 290 vision (e.g., hollow face). Arguably, most action guidance is based on unconscious  
 291 visuomotor processing of peripersonal space.

292       Still one should not take this type of dissociation as evidence that there are no  
 293 interactions between peripersonal perception and action. Consider now the following  
 294 version of a relatively weaker hypothesis, which Clark (2001) calls the assumption of  
 295 experience-based selection:

<sup>10</sup> In his paper 'Visual experience and motor action: Are the bonds too tight?', Clark (2001)'s discussion is on the relation between perception and action in general. Here I apply his way of framing the debate on peripersonal perception only. I shall consider differences with the perception of far space only in the next section.

296 Conscious visual experience presents the world to a subject in a form appropriate  
297 for the reason-and-memory based selection of actions.

298 The role of perceptual experiences is relatively modest on Clark's view, too modest, I  
299 would argue, to account for the special case of peripersonal perception. On this view  
300 indeed, perception remains relatively detached from the motor system. This can work  
301 when there is time. For instance, imagine that you are driving in Paris trying to reach  
302 the Eiffel tower, which is still far away on your left. This content gives you a rough  
303 indication of location you should be heading at and can be used by your spatial and  
304 practical reasoning (e.g., if it is there, that means that I should turn left at one point). It  
305 helps you in the selection of your itinerary but this takes place at the executive level,  
306 and not at the motor one. The time scale and the spatial scale are such that they cannot  
307 directly feed your motor system. I believe that one can be more ambitious in the case  
308 of peripersonal perception and propose that it can have a direct impact on the selection  
309 of action, instead of an indirect one:

310 Conscious visual experience presents *peripersonal space* to a subject in a form  
311 appropriate for the *motor selection* of actions.

312 Maravita et al. (2003, p. 531) define peripersonal space as the space "within which it  
313 [the body] can act". But one should probably add the space within which it can act  
314 *here and now*. Consequently, peripersonal perception cannot afford to be relatively  
315 detached from the motor system, at a more abstract level or in a different time frame.  
316 Roughly speaking, the motor system does not have the time for the reason-and-memory  
317 based selection. What is close to you in space can also be close to you in time,  
318 whether because you are approaching it or because it is approaching you. This is why  
319 peripersonal space is represented in a multisensory manner. And this is why whatever  
320 one sees in peripersonal space must be able to directly connect with what one does.  
321 Finally, as we saw earlier, for peripersonal perception to be of direct use by the motor  
322 system, it must be anchored in what one can do and it thus needs to keep track of the  
323 types of movements that one can actually perform at each moment.

324 However, this does not entail that peripersonal perception specifies the precise way  
325 actions are achieved. It contributes only at the level of the motor selection of the specific  
326 type of action. In Grush's (2007) terms, peripersonal content can give type-selecting  
327 dispositions, but not details-specifying dispositions.

328 A type-selecting disposition is something about the stimulus that motivates the  
329 execution of this or that behavior type, as opposed to nothing or some other behav-  
330 ior type. For instance, a bright flash might motivate a head turn and foveation,  
331 but not a grasp; an itch might motivate an arm and hand movement and scratch,  
332 but not any eye movement. A detail-specifying disposition is a disposition that,  
333 for any given behavior type (such as a grasp or foveation, or whatever), specifies  
334 the details of how that behavior type will be executed if it is executed. So for  
335 example will my intended grasp (behavior type) be implemented by moving my  
336 hand like this, or like that? (Grush 2007, p. 393)

337 Grush's distinction is important if one does not want peripersonal perception to fall  
338 back into Clark's experience-based control assumption. To make it clear, the hypothesis

339 is that the perception of the object close to us directly contributes in selecting the type of  
340 movement (arm withdrawal, for instance), but it not does provide the exact parameters  
341 on how to perform it.

## 342 **2.2 Where are affordances?**

343 Some may grant that peripersonal perception plays a type-selecting role at the motor  
344 level but deny that it is its exclusive privilege. Instead, they may argue that the percep-  
345 tion of far space can play the same role and that one can perceive *everywhere* what has  
346 been called affordances, that is, dispositions or invitations to act. According to Gibson  
347 (1979), affordances are simply properties of objects, which somehow supervene on  
348 their physical properties. In brief, to be graspable is not to be close to a hand that can  
349 grasp but rather to “have opposite surfaces separated by a distance less than the span  
350 of the hand” (Gibson 1979, p. 133). It has been later suggested that affordances are  
351 relational properties (the object is graspable *for me*) (e.g., Chemero 2003). In favour  
352 of this view, one may cite a series of studies by Proffitt and his colleagues, which  
353 found that when participants wear heavy backpacks they overestimate the slope of a  
354 seen hill in front of them (Bhalla and Proffitt 1999). Proffitt’s hypothesis is that our  
355 physiological state at least partly determines our perception. The relation to the sub-  
356 ject is then understood in terms of her abilities, and not of proximity: the hill is seen  
357 as climbable for me given the weight that I carry, but it is so wherever it is located.  
358 There is no temporal or spatial immediacy attached to the notions of affordances: the  
359 location at which objects are seen is simply irrelevant. On this view, perception in  
360 general can have action-oriented content. It then becomes more difficult to understand  
361 what privileged relation, if any, peripersonal perception has with action.

362 There is, however, a different interpretation of affordances.<sup>11</sup> For instance, Tucker  
363 and Ellis (1998) propose that I see the chair as sittable, or the pen as graspable, but  
364 only when the object is close to me. It does not entail that when it is far away I  
365 have no knowledge of what I can do with it. The hypothesis is *only* that my visual  
366 experiences present it in dispositional terms only when it is my immediate surround-  
367 ing. This may seem in contradiction with Proffitt’s results but their interpretation is  
368 actually controversial. According to Durgin et al. (2009), the found effect does not  
369 result from the participants’ visual experiences but from their cognitive expectations  
370 about the experiment: the participants look for a reason of why they were asked to  
371 wear a backpack and relate it to their knowledge that climbing a hill is harder when  
372 carrying a heavy bag. Consequently, one can make the effect completely disappear if  
373 the experimenters give to the participants another explanation for wearing a backpack  
374 (e.g. “the backpack contained electromyographic equipment designed to measure their  
375 ankle muscles”). Furthermore, some other sensorimotor effects appear to be specific  
376 to peripersonal space, such as the stimulus–response compatibility effect. Here is an  
377 example of this effect. Participants are instructed to press a button either with their left  
378 hand or with their right hand depending on whether the object is upright or inverted.  
379 Motor responses are facilitated if the graspable part of the object (e.g. the handle of a

<sup>11</sup> There have been many interpretations of the notion of affordances (see Caiani 2013, for instance) but I will focus here only on this alternative.

saucepan) is aligned with the hand that responds. What is interesting is that the effect works only when the object is within peripersonal space (Costantini et al. 2010).

Where, then, can we perceive affordances? Eventually it may depend on the definition that one gives of the notion. What is crucial, I argue, is the kind of practical knowledge of one's abilities that is used. If one assumes that affordances *merely* consist only in what one can do with an object in general, or even what human beings can do, then their relation to action is relatively remote; they are connected to one's motor expertise based on a history of successful actions, but they are not directly connected to one's actual motor abilities and plans. There is no reason why practical knowledge of this kind should be restricted to the space upon which one can immediately act. Hence, if it is true that one can see such affordances, then one can see them relatively far away.

Alternatively, one can assume that affordances consist in what one can do *here and now* (as in stimulus–response compatibility effect). Their relation to action is then more direct and because it is more direct it is more likely to be specific to the perception of the space within which the body can act, to use Maravita's phrase. This latter definition of affordance is closer to Koffka's (1935) original notion of *demand character*, which inspired Gibson, or to Siegel's (2014) more recent notion of *experiential mandates*. For instance, Koffka describes that you feel that you *have to* insert the letter in the letterbox when you encounter one. One may assume that you do not experience the pull of such an attractive force when the letterbox is far. In brief, when you see it next to you, you feel that you have to mail your letter whereas when it is on the other side of the street, you do not feel it. One way to interpret Koffka's view is then to say that what he calls the "geographic environment" is the far space, whereas what he calls the "behavioural environment" is peripersonal space, and only the latter is organized by a field of forces (attractive or repulsive) between the objects and the agent. Consider now Siegel's examples. On her view, when you experience mandates, you experience not only solicitation, but also motivation to act: "From your point of view, the environment pulls actions out of you directly." (Siegel 2014, p. 53). For instance, some types of music invite you to dance and you feel you are mandated to respond to it. What rationalize your dancing are the properties of the music itself. Siegel proposes that the content of the experience is of the type: [it is answered that the music is to be danced]. She calls this content the answerability content. What is important here is that her notion of answerability is relatively strong. She wants to draw a distinction between the described case, in which you feel you have to answer to the call of music, and a different case, in which you simply feel invited to dance and you do not know whether you should do it or not. Only in the former case do you feel mandated; only in the former case does your perceptual experience *directly* motivate you to act on it. The difference here may be between seeing a piece of chocolate simply as eatable (that can be eaten), and seeing it as yummy (that should be eaten). Only in the latter is the relation to action is direct:

Experiencing <yummy>, the child is drawn to put more chocolate in its mouth. It is so drawn not as the result of some further cognitive or inferential step. None is needed (...) The present point is that no further cognitive step is necessary to mediate the connection between the content and the action in the case of <yummy/yucky> contents. (Cussins 2012, p. 24)

426 It then seems that most of Siegel's examples describe situations in which the subject  
 427 can immediately act. For instance, she describes that you feel that you need to plop  
 428 down on the bed because it looks fluffy and that you need to adjust your interlocutor's  
 429 hair because it covers one eye. Can you experience such mandates when you see  
 430 the bed or your interlocutor from far away? You may feel that the bed is inviting  
 431 you, but not that you have to plop down on it. If we take seriously the answerability  
 432 content that Siegel posits, then it seems that its background requirement is that one  
 433 is actually in position to immediately answer it. She clearly states that the content  
 434 cannot be simply [it is to be answered] because this is too prospective. It has to be [it  
 435 is answered]. The hypothesis then is that one experiences a feeling of answerability  
 436 when one takes oneself to be able to do something about it *here and now*. In other  
 437 words, one experiences character demands when one is ready to act. This requirement  
 438 is precisely what characterizes peripersonal perception.

### 439 3 The peripersonal demand hypothesis

440 Based on the analysis of the conditions to experience mandates, one may be tempted  
 441 to defend the following view, which I call the peripersonal demand hypothesis:

442 One can experience mandates only when the seen property or object appears  
 443 as being located in peripersonal space. The perception of far space does not  
 444 normally present the subject with actions that she needs to answer to.

445 However, as we shall see, this hypothesis is too strong and I will suggest alternative  
 446 versions that are more likely to succeed.

#### 447 3.1 A matter of degrees

448 From now on I will put to test the peripersonal demand hypothesis by analysing a series  
 449 of apparent counterexamples. Let us go back to Siegel's music scenario. It is a difficult  
 450 case because the spatial content is not clear here. Still one may easily imagine that even  
 451 if it is heard from far away, one can still feel the urge to dance. The question, however,  
 452 is whether it is your auditory content on its own that makes you experience the need to  
 453 answer the call of the music. It rather seems that there is an affective dimension here.  
 454 In short, you love this music and the pleasure you have when listening to it pushes you  
 455 to act. By contrast, the peripersonal demand hypothesis requires the perceptual content  
 456 itself to have a motivational force. Interpreted this way, the music example does not  
 457 invalidate the hypothesis. Let us then consider a non-affectively loaded example, based  
 458 on a true story. The former French President Hollande had often his tie slightly tilted  
 459 when he was on TV and many French citizens felt the urge to adjust it. Siegel might  
 460 interpret such a case in terms of answerability: the spectators felt mandated to adjust  
 461 the President's tie, although it was not within their reaching distance. Here again, it  
 462 is possible to defend the peripersonal demand hypothesis. First, one may reply that  
 463 although it is true that the spectators could not objectively touch the tie, they were  
 464 under the spatial illusion that they could touch it. What they experienced would be

comparable to the startle reflex to draw away that one has when one sees something scary suddenly appearing on the screen. Alternatively, one may reply that what they experienced was only a desire based on their visual experience of the tilted tie. If this were the case, then the visual content had no motivational force on its own.<sup>12</sup>

Still one may argue that there are other cases in which one experiences the demand character of objects located beyond the immediate surrounding of one's body. Let us imagine, for instance, that you are in a construction site operating a power shovel. You then see that there is a steel bar ready to fall. You may then visually experience that you have to catch it, although the bar is at 10 m from your body. However, here I would argue that your visual experience is peripersonal and this is why it plays such a motivational role. Peripersonal space should not be understood in metric terms: it is not simply the area up to 30 cm surrounding the body. What is perceived as peripersonal space depends on a range of factors, and more specifically on motor ones. If for one reason or another (such as using a tool) one takes oneself to be able to immediately act on something, although it is relatively far away, one can represent it as being part of one's peripersonal space. Hence, the steel bar scenario does not constitute a counterexample to the peripersonal demand hypothesis.

There may be more cases in which it seems that one experiences a feeling of answerability for objects beyond the immediate surrounding of one's body but to argue that the peripersonal demand hypothesis is false, one would have to show (i) that one feels motivated because of the visual content itself, and not because of the emotions or the desire triggered by the visual content, and (ii) that one does not represent the space in which the objects are located as being peripersonal. The problem is that it may be sometimes difficult to disentangle between these various cases, and thus to positively assert that visual experiences for extrapersonal space can never have answerability content. One may then propose a relatively weak interpretation of the peripersonal demand hypothesis. On this version, the difference between the perception of far space and close space is not a matter of all or nothing but more of a continuum. Hall's (1969) notion of bubble is inaccurate because it entails a sharp boundary between what is inside the bubble and what is outside. Instead, one should talk of a *field* characterized by its gradient, similar to the magnetic field. One may then say that if it is true that one can experience mandates, then it is more likely to happen in the case of peripersonal perception than in the case of the perception of far space. Alternatively, one may claim that the feeling of answerability is experienced more vividly when objects are next to the subject but she can still experience it even for objects that are far. One may also suggest that they can be experienced with a stronger degree of urgency when they are close. The gradient hypothesis has probably some truth in it but it remains to understand the direction of the gradient: why is the force more powerful when the

<sup>12</sup> One way to settle the debate between the two interpretations is to determine whether the spectators displayed some kind of motor readiness to act. Arguably, there is a motor proxy to the feeling of answerability. When experiencing a mandate, one feels that one needs to act and doing nothing then is only inhibiting an urge to do something. This urge most probably results in some level of motor activity. In the music case, for example, when you feel that the music is calling you and that you have to dance, you may start making small rhythmic movements that you cannot help doing, not yet real dancing steps, but still something. If the spectators show no motor readiness to adjust the tie, even inhibited, it then means that they do not feel mandated to do it.



503 object is seen as close? I will propose that there is a fundamental difference between  
504 close space and far space beyond quantitative variations.

### 505 3.2 Semper paratus

506 We just saw that it is difficult to fully rule out the possibility that extrapersonal experi-  
507 ences can have answerability content. Neither does one want to claim that peripersonal  
508 experiences always have answerability content. Arguably, there are many cases in  
509 which one's environment is neutral and one does not feel mandated to do anything.  
510 Still, I argue, peripersonal perception does not have the same relationship to action as  
511 the perception of far space. The hypothesis that I will now defend is the following.  
512 In short, peripersonal perception specifically evolved for one to experience mandates,  
513 while this is not the case of the perception of far space. Mandates are present-directed:  
514 they are about what one has to do now. Feeling that one needs to answer to what one  
515 perceives implies feeling ready to do it. I will now argue that peripersonal percep-  
516 tion is characterized by this readiness to act because it was designed for situations in  
517 which one has no choice but to act, namely, when one is under threat (Graziano 2009;  
518 Brozzoli et al. 2012).

519 It was the Swiss biologist Hediger (1950), director of the Zurich zoo, who actually  
520 first noted that animals do not process space uniformly and in particular that there is  
521 a specific zone immediately surrounding their body, described as the flight distance,  
522 that predators cannot approach without eliciting specific defensive responses (flight,  
523 freeze or fight depending on how close the predator is):

524 The satisfaction of hunger and sexual appetite can be postponed; not so escape  
525 from a dangerous enemy, and all animals, even the biggest and fiercest, have  
526 enemies. As far as higher animals are concerned, escape must thus at any rate  
527 be considered as the most important behavior biologically. (Hediger 1950, p 20)

528 Since Hediger, it has been generally accepted that peripersonal perception evolved  
529 as the perception of a margin of safety, which is encoded in a specific way to elicit  
530 protective behaviours as quickly as possible if necessary. For instance, it has been  
531 shown that direct electric stimulation of the bimodal neurons involved in peripersonal  
532 perception elicits protective responses. Less invasively, the perception of stimuli close  
533 to the body elicits avoidance behaviour (for review, Graziano 2009). In humans too,  
534 it has been shown that the perception of an intense sound near the hand can cause a  
535 defensive-like freeze response, resembling that observed during the presentation of  
536 noxious stimuli (Avenanti et al. 2012). Recent results in neuroimaging also show that  
537 when one perceives a salient stimulus close to one's body through vision or audition  
538 one activates the same brain areas as those that are activated when one is in pain  
539 (Legrain et al. 2011). Furthermore, it has been described that patients who suffer from  
540 pain asymbolia lack reaction not only to painful stimuli, but also to dangerous ones  
541 close to their body (Grahek 2001). It may then seem that the right evolutionary model to  
542 understand peripersonal perception can be found in the analysis of pain. At first sight,  
543 they have much in common. Peripersonal perception motivates protective behaviours  
544 and it justifies why we act in the way pain does. The perception of ~~close threats~~ is

545 clearly the most convincing example of mandates. If there is a time at which we really  
546 feel we have to do something is when a cobra snake gets close to us. Our perceptual  
547 experience of the snake next to our foot makes intelligible why we feel mandated to  
548 withdraw our foot. If we had perceived it far away from our body, we would not be  
549 able to justify why we moved in such a way. The rationalising property of protective  
550 responses in such a case consists in the peripersonal content.

551 I thus propose that the feeling of answerability is precisely the reason for which  
552 peripersonal perception evolved, while this is not the case for the perception of far  
553 space. Roughly speaking, only peripersonal perception was designed to follow the  
554 old Scout's motto: "Semper paratus". From an evolutionary perspective, peripersonal  
555 perception is always prepared to make one act because it originally evolved for the  
556 purpose of the detection of close threats and self-defence. From a neuroscientific per-  
557 spective, peripersonal perception is always prepared to make one act thanks to its  
558 implementation within brain structures involved in action guidance. From a computa-  
559 tional perspective, peripersonal perception is always prepared to make one act because  
560 it is informed by what one can and cannot do at each instant.

561 Nonetheless one may be tempted to reject even this qualified version of the periper-  
562 sonal demand hypothesis on the ground that some threats need us to react very quickly  
563 even when they are still far away. As noted in the introduction, if I see a lion thirty  
564 meters away from me, I should feel mandated to do something about it (such as freeze  
565 or run). It would be already too late if the lion were only 30 cm away from me. This  
566 example, however, does not refute the new proposal. One may indeed argue that in  
567 the lion example, the source of the motivation that I experience is not to be found in  
568 the visual content itself but rather in the fear that I experience. If I were not afraid,  
569 I would most probably not react at all. But could one not offer the same analysis for  
570 peripersonal cases? When I see the snake close to my foot, there is no doubt that I  
571 am frightened by it and that my fear motivates me to avoid it. The crucial question is  
572 whether this is the only source of motivation that I have. It does not seem so. We saw  
573 earlier that defensive responses can be artificially induced simply by directly stimu-  
574 lating the brain areas involved in peripersonal perception (Graziano 2009). There is  
575 no fear experienced in such a situation and yet the monkey automatically engages in a  
576 range of protective behaviours. In order to show the motivational role of peripersonal  
577 perception per se, one can also look at less frightful scenarios. As argued, peripersonal  
578 perception evolved because of threats but fortunately we rarely meet snakes and other  
579 predators. Nonetheless, peripersonal perception constantly plays a motivational role  
580 in our everyday urban life. It is enough to navigate in a room full of furniture or in a  
581 street full of people. Seeing an obstacle such as a chair on one's path does not elicit  
582 a feeling of fear. Yet one avoids the chair. One leans away from visible objects, and,  
583 when walking through a doorway, one tilts one's shoulders to protect one's body from  
584 hitting the doorframe. The thing is that if one stops paying attention to peripersonal  
585 space, as this occurs in the neurological syndrome of peripersonal neglect, one col-  
586 lides more into objects (Nijboer et al. 2014).<sup>13</sup> Peripersonal perception has an intrinsic

<sup>13</sup> It is interesting to note that there is a three-fold dissociation between personal neglect (bodily space), peripersonal neglect, and extrapersonal neglect. Furthermore, a study that investigated the motor performance of monkeys after a lesion of their ventral premotor cortex (V6A), a cortical area responsible for

587 motivational force, which is not borrowed from fear. This allows a direct connection  
588 for action, which is literally vital when our body is under immediate threat.

## 589 4 Conclusion

590 There is a certain degree of emergency when it comes to peripersonal space, not as  
591 much as with pain, but still a lot more than with the rest of my perceptual field. This  
592 emergency and the necessity to always be ready for impact that follows from it raise a  
593 number of computational challenges specific to peripersonal perception. In this paper,  
594 we saw the sensory and motor specificities of peripersonal perception. To reply to the  
595 question we started with in the introduction, we can now reply positively: seeing the  
596 rock close to my foot does differ from seeing the moon in the sky. However, there are  
597 many questions that are still left unanswered. In particular, what kind of content do  
598 peripersonal experiences have? For sake of simplicity, I adopted Siegel's proposal of  
599 answerability content but one may wonder whether this is the right way to analyse the  
600 content of peripersonal experiences. Given the similarities between pain and threat  
601 perception highlighted earlier, one might wonder whether the theory that is true for  
602 pain may ~~not~~ also be true for peripersonal experiences, at least for those that are about  
603 threats.<sup>14</sup> The challenge is then to understand how to spell out this content, whether it  
604 is of pain or of peripersonal experiences. Some argue that it is imperative (Klein 2015;  
605 Martínez 2011); others say that it is evaluative (Bain 2013). This debate goes beyond  
606 the present paper but it remains that the relation to action that pain entails appears  
607 to be a promising path to explore the motivational force of peripersonal experiences.  
608 It further reveals that we are far from standard models of perceptual content.

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Footnote 13 continued  
peripersonal perception, described that the monkeys started to hold their arm close to their body and  
refused to spontaneously move them (Battaglini et al. 2002). This may follow from the lack of conscious  
experience of their immediate surrounding.

<sup>14</sup> Siegel (2014) herself suggests that the answerability content must have a valence.

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