Safeguarding the Space Around Us – the Role of Peripersonal Neurons in Social Imagery

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Abstract

Introduction: *Psychotherapeutic work with the Social Panorama Model shows the crucial role of nearby social imagery in intimate relationships: an intimate relation is created by putting the image of the person with whom the relation is maintained on a close location in one's mental space. In general, the parts of the brain involved in imagining a stimulus are about 90% the same as those activated while actually perceiving such a stimulus. Does this also hold for the class of brain cells called peripersonal neurons? These peripersonal neurons alert a being when its adjacent sphere of space becomes invaded. In case these peripersonal neurons also respond when such threats are imagined, this may have strong implications for intimate social experience and particularly the sense of love and aversion.*

Objectives: *To find a space related to neuroscientific underpinning for intimate social experience. This may pave the way to more precise psychiatric diagnosis and more effective psychotherapeutic interventions.*

Methods: *Comparing the output-levels of single peripersonal neurons during the perception and imagining of close social stimuli is a too invasive paradigm in humans and we are still far from making primates reliably imagine their loved ones. Therefore, alternatively it was chosen to regard the Social Panorama experiments with intimate relations as our main source of information. These data consist of numerous photographs of the spatial spread of the imagined locations of loved ones (and ex loved ones), from large numbers of subjects. This data appears quite consistent. On the base of established neuroscientific research into peripersonal neurons, we interpret the mechanisms involved in the phenomena as Social Panorama experiments. We relate these mechanisms to clinical disorders like depression and Asperger.*

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Results: *Social Panorama experiments show the spatial placement of loved ones in relation to the self. It is clear that loved ones are represented in locations that vary from inside the body, on the skin, to everything up to arm length away. If peripersonal neurons respond to social images in these regions of space, this must have a great influence on the pleasant feelings raised by loved ones and also on the adverse impulses towards strangers and disliked individuals. Malfunctions of this may have clinical impact.*

Conclusions: *The recent paradigm of mental space psychology promotes a transdisciplinary view on the working of the psyche and it is unique in taking space as the primary organizing factor in the mind. For the latter one finds clear evidence in neuroscience and in the practical use of spatial psychotherapeutic tools like the Social Panorama. Several far-reaching hypotheses unfold themselves when probing these connections. The findings are applicable for improving clinical interventions and also as diagnostic tools.*

Keywords: Social Panorama, peripersonal neurons, neuroscience, mental space, Asperger, Depression

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I. Introduction

Where in the space around our body we imagine things may be quite meaningful to us and can lead to expressions like: *It appears in my face! It seems towering over me. It feels out of reach. This issue blocks my way*.

The tight link between, on the one hand, the three-dimensional nature of human experience and, on the other, the spatial linguistic grammar, was uncovered by George Lakoff (1987). Currently, the central role of orientation and navigation in all human cognition features the field of *spatial cognition* (Tversky, 1993, 1999; Burgess, 2014). To those involved in that area of enquiry, it became clear that, all we think of, all we visualize, all we feel and all we hear appears on a certain location in the mental sphere in and around us (Fauconnier, 1997; Derks, 2016). Identical conclusions were drawn by: Tversky (1993), Tversky & Kessel (2014), Levinson (2003), Spivey, Richardson & Zednik (2010), Barsalou (2012), Groh (2014) and Bellmund et al. (2018). Two univocal citations: "All cognition is spatial in nature" (Tversky, 1999) and "Space is the medium of thought" (Pinker, 2007). This vision, combined with the experience with psychotherapeutic interventions in the client's spatial experience, resulted in a new paradigm named *Mental Space Psychology*. Mental space psychology reveals the ubiquitous role of space in all experience and cognition, from logic, design, psychotherapy and social life (Derks, 2016; Manea & Beenhakker, 2017).

Relationships in space

Even the emotional quality of our relationships is characterized by *where* we locate the images of people. Verbal expressions illustrate this: Are you *backing* me up? I look *up* to her. He *confronts* me. The importance of location in social life is paramount in the so-called *Social Panorama Model*, as developed by Derks during the 1990s. To be more precise, the Social Panorama Model is used as a psychotherapeutic tool that builds on the assumption that any person with whom we interact on a regular basis – with whom we have a relationship – holds a stable position in a person's 3-D cognitive-imaginary social landscape (Derks, Oetsch & Walker, 2016). This unconscious panoramic view represents the social reality to a person. It informs the person about who is who and what their own role and position are in between these persons. Derks (1997, 2005, 2016) showed the relative ease and accuracy by which people can point out the location where they hold their social images, and also that, the position of such images correlates with social emotions, like authority, belonging, love and conflict (Derks, Oetsch & Walker, 2016). Thus, the locations of the representations of people in this panoramic map establishes the quality of the relationships, which in its turn is decisive for social behavior. For example, a close friend will be visualized near and the interaction will be casual, warm and friendly; a feared authority is probably seen up high, far and central, and may be avoided at all costs.

Relationships in the brain

The neuro-anatomical meeting ground of "socio-emotional" and "visuo-spatial" is generally believed to be the right cortical hemisphere (Bugousslavsky & Cummings, 2000). Although with all allocations of tasks between the hemispheres, inconsistencies are common (Whitehouse and Bishop, 2012). The (yet untested) hypothesis is that most social cognitive activity made visible in the Social Panorama experiments in this study does require an intact right hemisphere. Therapeutic practice also shows that in order to find the locations of where the images of people are held in mental space, the subject needs a relaxed state of mind – typical the concentration associated with a light hypnotic trance (Derks, 2005). Many therapists believe that this mental state enables the subliminal (intuitive) awareness of right hemispheric content.

The processing of spatial information – from the level of locating objects to the complexity of creating 3-D social maps – is so fundamental, unconscious and obvious that in everyday life we hardly reflect on it. What we thus disregard is that our brain must do pretty complex 3-D calculations. In this paper we focus on the space just around our body, the intimate space, in which we meet our real loved ones and where we also imagine them in our mind. So, the major question is how does a brain achieve all of that? To give a primer – among the key players enabling spatial cognitive modeling are the so called "peripersonal neurons".

Peripersonal neurons

The ability to judge the whereabout of oneself within the environment seems largely hardwired in the brain: the mind, as it were, holds (or is) a "navigation system" (Burgess, 2014) and it also contains a kind of "radar" (Graziano, 2018). This latter surveillance tool warns an organism against incoming danger. It also serves a more trivial function – we must know our position in relation to the objects around us. Since otherwise we would constantly bump, stumble and knock things over. In addition, we do not like it when

certain others get too close. It appears that we have a personal safety zone around us and flinch when this is invaded (Graziano, 2018).

In the 1980s neuroscience was rattled by the discovery of peripersonal neurons. In order to comprehend this excitement, one must first understand: neuroscientists, traditionally, love to categorize neurons on what type of stimuli they respond to. This seemed largely to correspond to the sensory modalities these cells were connected to. That is why there are visual neurons, olfactory neurons, tactile neurons and movement-related neurons. The latter are nerve cells that are active during a movement or during the preparation for movement. Vestibular cells respond to balance. Very specialized for navigation are place cells that respond to certain locations (O'Keefe & Nadel, 1976), that together with grid cells help the organism to know where in the world it is (Burgess, 2014). As you see, even at the level of neural processing things are highly spatial – space seems not only the star in cognition, location is also a primary coding principle in the brain (Burgess, 2014; Wilimzig & Derks, 2018; Bellmund et al., 2018).

Peripersonal neurons are different because they respond to rather complicated stimuli: they are multi modal. They do not only react to vision but also to touch. They have a tactile receptive field, which means a particular area of the body where even the slightest feathery fondles trigger them to fire. But they also respond if something is only approaching that tactile receptive field or just comes close to it. For that to be possible, they must combine a tactile *and* a visual response, which instigated the puzzling among neuroscientist.

Peripersonal neurons must also do something like a distance computation – since the closer the stimulus gets to their tactile receptive field, the fiercer they fire. Thus, they help monitor the trajectory of nearby moving objects. Different individual peripersonal cells respond to specific parts of the visual field and the body. Sometimes, their monitored area is small, at other times it is rather large. If you put all these areas together, they form a safety bubble around the body. And when the body or parts of it moves, this bubble reshapes itself along. Close to the body these cells are more responsive than beyond reaching distance (Graziano, 2018).

Like Vittorio Gallese (2015) stated, in regards to the *mirror neurons* he discovered: "Everything in the nervous system is connected to everything else, and *one* mirror neuron alone can do nothing by itself." So, when we talk about the capabilities of peripersonal neurons, we must also imply a necessary cooperation with other cells to make them do their work.

The earliest mention of peripersonal neurons seems to be in the 80's (f. e. Rizzolatti et al., 1981; Gentilucci et al., 1983, 1988). Researchers found peripersonal neurons in parts of the brain that at first were believed to just govern movement (f. e. Colby et al., 1993). Rizzolatti and colleagues found these cells to form a patchy network that stretches out on the cortical surface and also into the deeper parts of the brain (Luppino et al., 1999; Matelli & Luppino, 2001; Gharbawie et al., 2011; Kaas et al., 2013).

What happens if one reaches out to someone, into the space where a peripersonal neuron keeps guard? The somewhat surprising answer is... nothing. These neurons are not directly linked to any grasping, shielding or fencing reflex. Peripersonal neurons give a purely passive sensory, perceptual response. That peripersonal neurons restrict themselves to only sending out passive "alarm signals", follows from experiments done by Graziano (2018). However, this research was never published in a peer-reviewed journal, as his conclusions were considered to be a *negative outcome* by the evaluators – a clear down side of peer review.

Keeping track of the surroundings

Imagine, it is night, suddenly all lights switch *off*, making it pitch black. Are you entirely lost without any visual input? The simple answer is... no, you are not. If an object is close to you and a peripersonal neuron on guard is noticing its presence, it will even fire up when you get closer to it and may fall silent when you move away from this thing, just depending on the previously registered location (Graziano, 2018). That the brain constantly maps the environment can be easily tested: "Now close your eyes and imagine to walk to the front door, go out and find your vehicle." You find it since your mental map was already available. Or "Get into your kitchen, close your eyes or be blindfolded, and fry an egg." The mind constantly creates maps and automatically updates them on the go. Within all of that, the peripersonal neurons help to map the situation at close range. When they do that right, it means that the location of objects is still known to a person without actually perceiving them.

The *Muzieum* (Museeum) in Nijmegen, Netherlands is an exhibition where the visitors are guided by fully blind volunteers through an entirely dark environment – to familiarize them with the experience of the completely blind. The excursion can be "Holiday in Thailand". A group of 6 is led through corridors, along an airport counter, a baggage belt, over a bridge, then to a market followed by a boat trip, all ending in a

bar. There one must pay, by relying on the tactile properties of money. Finding your own drink back, talking to the person beside you, to discover a second later that she is gone, belongs among many other sensations to what can be attributed to peripersonal neurons at work. However, knowing that something is still somewhere, after a sudden black out, seems to happen for a part in the retina but largely in the visual cortex, in the shape of a so-called afterimages (Dong, Holm & Bao, 2017). But that is not so much what we are speaking of when we mean the response of peripersonal neurons to imagined stimuli.

Close range mental imagery

One might argue that all is fine so far but that we are still talking about real stimuli – actually present ones and also remembered material ones. So how about the things people fully create in their phantasy? Imagination has triggered the imagination of philosophers through the ages: how do we mentally construct things that do not exist? Considerations can be found in Plato's work and there is a rich literature on this topic in modern psychology (f. e. Mckellar, 1957, or more recently Ganis et al., 2004). Conclusion: the better part of what is going on in people's minds is imaginative in nature – and many say it counts most when it comes to psychological problems.

For instance: a germophobia functions only in one's phantasy since the stimuli are not perceivable. Does maneuvering around a supposedly infested door handle involve peripersonal neurons? How about victims of sexual abuse: even decades later, they may visualize others doing bad stuff to them and freeze of fear and disgust. Is it their peripersonal neurons that help that to happen? Now, suppose a boxer preparing himself for a match: he imagines blows to his head and how to evade these. These imaginary stimuli breach his personal space, does that alarm his peripersonal neurons? And what happens when a teenager fantasizes a kiss?

On the base of what is generally dealt with in psychotherapy, we must conclude that a lot of abnormal and also normal thought consists of imagined concepts, and social life offers a well-documented example thereof. All social objects in the Social Panorama represent people in a schematic manner – people who exist in the real world, but not only and also fully fictional ones like Father Christmas, the grim reaper, ghosts, Beelzebub, the Easter Hare, spiritual entities and metaphorical beings. What is called someone's *social panorama* is an imaginary 3-D construction that people build based on the lifelong experience with others. It represents inter human relationships of any type. And since intimacy requires proximity, varying from just in touch, to skin-to-skin, for closeness with loved ones is the standard. Within this spatial social landscape, *someone* can also be too close for comfort and that may raise strong emotions too. In mental space based therapeutic practice, it is common knowledge that any psychological issue, like traumas or depressions, are directly linked to images on too close for comfort locations (Derks, 2005, 2018). Psychotherapeutic approaches that are informed by mental space psychology work a lot with the shifting of worrisome images to better (further) locations. And this type of spatial therapeutic work has a surprisingly strong impact (Beenhakker & Manea, 2017).

II. Method and results

Social imagination in peripersonal space

An experiment Derks (2005, 2016) has frequently conducted within social panorama workshops is: Feel the feeling for your loved one. Next, find the location of your loved one in your mental space: define the distance, size and the direction of the gaze... Next, put the image of an unfamiliar person on exact the same spot...

When this is done with a group of students, they may signal strong aversive responses. "That stranger can't be so near!"

Since we do not know about experiments in which the firing rate of peripersonal neurons was registered in relation to imaginary stimuli approaching their tactile receptive fields, the question is: how can we connect the above to the activity of peripersonal neurons? This takes us to a more hypothetical form of reasoning. To make a long story short – mental imagery is considered easy to understand neuroscientifically, in large part because imagery draws on exactly the same cortical areas as used in perception (Kosslyn et al., 2007). To be precise, Ganis et al. (2004) estimates that perception and imagery rely on over 90% of the same brain areas. This suggests that apart from the specialized neurological structures involved in perception, the meaning of stimuli, real or imaginary ones, is produced by the same neurological tissue and probably in the same manner. Thus, if one considers the neurological equality of perception and imagery (memory) a fundamental property of the brain – and for visual imagery there is little doubt that it is (evidence exists for tactile imagery as well, Schmidt,

Wu & Blankenburg, 2017) – it is plausible to assume that it also holds true for peripersonal neurons. The only known evidence comes from the continuous firing of peripersonal neurons, even when the original triggering stimulus is not perceived anymore, like when the lights are switched off. One could safely argue that the model of the environment on which the brain relies in that situation is a form of imagination. Which may mean that peripersonal neurons respond largely in the same way to imagined stimuli as they do to actual stimuli. Therefore, the hypothesis is that imagined stimuli in general, and in particular of disliked people, dangerous animals, incoming flying objects, etc., when envisioned close, may bring the peripersonal neurons in a state of alarm.

"Biblical neurons"

Does the alarm go off for all invading objects? When testing peripersonal neurons in a macaque monkey, Graziano and colleagues (2018) stumbled across something that surprised them. Instead of using their regular emotional neutral Ping pong balls on a stick, the experimenters used stimuli with a more emotional valence. As a positive stimulus they used an apple, as a negative stimulus, a rubber snake. This laboratory monkey loved apples, so it gave every indication that it wanted to have that apple. On the other hand, most monkeys are afraid of snakes, even if they never saw one in their life – it seems to lie in their genes. Now a surprising thing happened – the peripersonal neuron under scrutiny *only* responded when the snake was presented within this neuron's particular receptive field. In contrast, when the apple was brought close, the response came to a halt. For what was surprising at first, Graziano found a rather logical explanation that goes like this: peripersonal neurons build a protective bubble around the body. For objects that the monkey desires, the defenses go down. The relaxed mental radar enables the animal to reach out for that object and get it. Thus, positive things are welcome in the protected space but potentially dangerous objects excite the peripersonal neuron up to the highest levels of alarm. So, the recognition of and valuing of incoming stimuli must be directly behind the habituation of the alarm function.

In his book "The Space Between Us: A Story of Neuroscience, Evolution, and Human Nature", Michael Graziano (2018) speaks of "Biblical neurons," because of the analogy to the Garden of Eden, when the monkey's peripersonal neurons love the apple and dislike the snake.

When the above is translated to the human world, this means primarily that we live within safeguarded bubbles of space. In fact, we live within several layers of radar, some protect at close range and other guard at more distance. In the social panorama, one may distinguish an *intimate sphere* in which we allow only people we recognize as intimate ones, and a *personal space* for those encoded as close acquaintances and then a *public sphere* for those rather defined as distant (Derks, 2016). The Social Panorama Model explains how we know what our relationship to an individual is, and where we have stored the image of that person in our mental space. So, when our beloved spouse approaches us, it may take some milliseconds for 1) recognition, 2) waking up the image in our mental space and 3) coming to the conclusion that the peripersonal alarm can be turned down, since where she/ he appears is at a distance that is encoded in the social panorama as positive. Those with whom we are intimate can invade our closest bubble and be welcomed, but the opposite holds for foreigners and even more so for extra-terrestrials!

Interestingly, there seem to be significant cultural differences in the distances kept to others (Hall, 1966). For example, conversating Finns may step backwards at distances where people from Brazil come three steps closer. Thus, a question for neuroscience is: in what measure are such social reactions the result of culturally adapted peripersonal neurons at work? And here again the image of one cell functioning on its own cannot explain the complexity of the achievement (Gallese, 2015).

In repeated experiments with intimate relationships, Derks (2016) made people first locate their partners and ex-partners in pairs in an uninformed manner. After that, the participants were invited to stick marked/ colored sheets of paper on the floor, on the spots where they have already found the locations of their partners and ex-partners (see Figure 1). In one group with 90 participants the outcome was counted. Surprisingly, 5% of the partners were overlapping with the self-position. About 27% of the partners were on the left and a similar amount was on the right side. The rest was straight in front. The distances, most important for our present study, were not measured, but still an estimated 95% of the partners were within arm's reach. In general, ex-partners were located at far greater distances (between 1 and 50 meters away) than partners. This is analog to partners resembling apples and ex-partners sometimes snakes! However, if ex-partners were still kept very close in a person's social panorama, this might signal polygamy.

Over the course of 10 years, this experiment resulted in a series of photographs that give a clear impression of the locations involved. Here are some typical examples. Figure 1 shows the results of a 25 participants group from the backside. Figure 2 presents the results of a group of 130 also from the backside and Figure 3 those of one of 13 participants from the front. Figure 4 shows the results from a group of 14 from the front. In these figures the darker (pink) sheets represent the locations of partners and the lighter (green) ones of ex-partners.

Figure 1

Figure 2

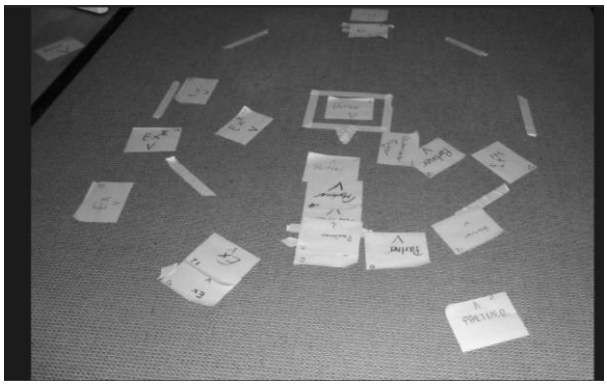

Figure 3

Figure 4

The analysis of about 80 of such group experiments resulted in a clear set of patterns. For the moment it is enough to see that there are many people who place their loved-ones in the close zone that intersects with the one safeguarded by peripersonal neurons. When much loved ones are tolerated this close, it coincides with the mental images of these loved ones being located there in the social panorama. In other words, the intimate relation does consist of having the image (called personification in the social panorama) placed within the intimate sphere (Derks, Walker & Ötsch, 2014).

From our knowledge about protective peripersonal neurons in mind, one can imagine it as follows: if we do not want our ex-partner close to us (within our intimate space) but he/ she is still positioned there in our social panorama, then whenever we think of him/ her it might be that our protective peripersonal neurons respond, leading to a fit of stress.

Therapists who work according to the principles of mental space psychology may help their clients to move the positions of the images of people they are no longer intimate with, or do not want to be intimate with, further away. There exist a series of working protocols to guide the therapist to achieve that with the client (Derks, 2006).

As already mentioned above, these experiments verify what is known from clinical work: people may hold the representations of others sometimes extremely close up to within their body space. The latter findings lead to several highly relevant observations. First, people that are diagnosed as “borderline” show a high level of images of others close or inside their body space (Derks, 2002, 2016). Second, it was pressing to also make the connection to the concept of *possession*, as used in religious and shamanistic traditions. The popular view on possession, that fits with the experience

of the victim and his/ her healers, always comes with the attribution of power to some entity that occupies a space within the body margins of the victim. Derks (2002) concluded that an exotic concept like possession makes far more sense if looked at from the perspective of the social panorama model. The symptoms then result from the images of others being located inside the body. In the social panorama model the latter is called "shared locations" and it comes with a diffusion of the locus of control and uncertainty about the identity of those involved: who wants, does and controls what? Clinical practice suggests that shared locations appear most in people capable of high levels of empathy, who were in a prolonged empathic relation with the entity (person) that came to possess them.

In regards to the functioning of peripersonal neurons in the above, the following questions seem relevant:

1) Does the inability to keep one's personal space free from others result from dysfunctional peripersonal neurons? Graziano (2018) describes social difficulties that he ascribed to dysfunctional peripersonal neurons.

2) In what measure is "the letting go of one's defenses", as often recommended for intimacy, an intentional switching off of the peripersonal radar system?

With these questions we enter the field of psychiatric diagnosis.

Towards a psychiatric diagnosis in mental space

To grasp the expression *mental spatial psychiatric diagnosis*, one needs to consider the following: in medicine an *initial diagnosis* is always based on the observed and expressed symptoms of the patient. The doctor may ascribe a treatment just on the base of that *initial diagnosis*, but when he suspects more serious ailments, they will do a more profound diagnosis (*differential diagnosis*) often by sending tissue or body fluids to the lab. And many more bodily things can be checked: by X-rays, blood tests, DNA-test, liver punctures, diagnostic operations, heart catheterization, biopsy etc.

In contrast, in current psychiatric diagnosis (DSM-5) the *initial diagnosis*, based on lists of observed and expressed symptoms, is all there is. There exists nothing like a *body* when it comes to psychological issues; this makes diagnosis in psychiatry so difficult. Only when neural dysfunctions are feared, brain scans or cerebrospinal fluid tests are done. However, the promise of brain scans helping clinicians to diagnose pure psychological diseases remains shifting ever further into the future. From a medical perspective, an fMRI scan diagnosis would be ideal. The brain however is an organ with hyper fast and super variable processes: the statistical interpretation of these does lead to impressive colorful images, but this is yet not precise enough to diagnose a phobia, depression, trauma, schizophrenia or a compulsion.

However, when it is true that all mental activity happens in mental space, no form of psychopathology can be excluded. Mental space can play a central role in clinical psychology as the place to look for a diagnosis (Derks, 2018). Mental space is as it were "the body of the mind".

The therapist needs to bring the patient in the right state of mind so that they become aware of what is happening in her or his mental space. 25 years of clinical practice with the social panorama and related methods, shows how doable this is. From there onwards, it all depends on the understanding of the characteristics of mental space. For instance, some early childhood traumas may be located at great distance (30 meters) from the self in the center, and still hold a strong "gravitational pull" on the present-day functioning of the client. Or a client may hold the representation of the future at their back: a situation that showed to be common in Andean Indians (Núñeza, & Sweetser, 2006). Since the past may be in the front then, a past oriented lifestyle is to be expected in such a person – where little motivation to study, or to invest in life insurance, stocks or savings can be expected. So, diagnosis in mental space might develop in to an additional or alternative tool to decide what creates someone's psychological issues.

When we return to the role of peripersonal neurons in psychological issues, it becomes nearly obvious that constantly held close to the body images can cause forms of permanent stress. Clinical work shows this with phobias, in posttraumatic stress disorder, in identity problems, in depression and by the lacking of them, in Asperger autism.

Phobias and fears

Clinical observations and common-sense show that a general coping strategy to deal with psychological problems is to place/ put/ move these at a distance (Thomas & Tsai, 2011; Davis et al., 2011; Walker, 2014). And that will mean outside the protective bubble of the peripersonal neurons. In the work with phobic clients, therapists see that a close image of a spider may have a nearly similar effect as a real spider coming up

close; one may hypothesize that the close imaginary spider sets off the alarm in peripersonal neurons.

In order to understand how stressful a violation of the peripersonal space can be, one has to look at the artificial stimulation of peripersonal neurons in the laboratory. Electrical stimulation of neurons has been the method of choice among neuroscientists for over a hundred and fifty years. Presumably it started in 1870, when two German scientists, Gustav Fritsch and Eduard Hitzig, evoked muscle movements in a dog – allegedly using Mrs. Hitzig's dresser as operating table, and by producing electricity with a hand-cranked electrostatic generator (Fritsch & Hitzig, 1870). Modern methods may use sophisticated microcurrents, administered over tiny electrodes that just reach a few targeted neurons.

If one stimulates peripersonal neurons this way (for obvious reasons this goes only with laboratory animals), a strong response is obtained (Graziano et al., 2002). Graziano (2018) describes what happened when he stimulated a peripersonal neuron that warns when objects threaten to touch the cheek:

- The eyes close.
- Muscles surrounding the eyes contract, pursing the skin around the eyes.
- Muscles in the cheeks contract. The upper lip is pulled up, protecting the eyes in folds of the skin.
- The nearest ear is folded back against the head as if the vulnerable earlobe is protected.
- The head is pulled sharply down and away from the stimulated site.
- The nearest shoulder shrugs. This provides some blocking protection to this side of the neck and face.
- The respective arm lifts in a sharp, fast movement as if to block an impending impact.
- The eyes are sucked back into the head (Cooke & Graziano, 2004).

By microstimulating a neuron that guards the top of the head for threats coming from above, this leads to the eyes closing and the head bending down. Wherever a peripersonal neuron is microstimulated, it leads to defensive actions to protect the monitored area of the body (Cooke & Graziano, 2004).

In the above experiments it was also found that the monkey got used to the artificial stimulation and the strange unplanned movements they make, and after a while it did not seem to bother anymore. However, one can assume that if real objects are threatening the body, this type of habituation will not take place. During real threats the anxious emotions can remain quite strong. Defensive actions due to the alarming impulses of peripersonal neurons parallel all characteristics of a "startle response," of the kind that happens in moments of extreme shock and fear. Graziano calls it the "most pure, stripped-down, primitive essence of self-protection" (Graziano, 2018, p. 7). Wildman (2013) calls this highly elementary response an "inborn reflex that organizes all our bodily stress": where the spine curves forwards, the person kneels down, chin low, shoulders risen, hands in a defensive position and the face contorts to protect the eyes.

Startle is heavily influenced by anxiety. People suffering from anxiety disorder have an enhanced startle reaction (f. e. Dawson et al., 2008; Grillon, 2008; Grillon et al., 1991). This shows the intricate relationship between fear and startle.

The question is, does this link between fear and startle apply to imagined stimuli too? Research into posttraumatic stress disorder and phobias paints a clear idea of the role of imagery in these issues (Brewin, Gregory, Lipton & Burgess, 2010).

High levels of adrenaline signals emotional stress and during the startle reflex adrenaline floods the body (Wildman, 2013). If a person imagines frightening stimuli within the protective bubble of peripersonal neurons on a steady basis, this leads to continuous stimulation of the startle reflex. According to Wildman (2013), muscles will tighten up to the point that it becomes painful. Compressed muscles in the back and belly set pressure on the spine. As the next step knees and hips start to hurt. The jaw can be continuously clenched. Over-adrenalization resulting in constant muscle contraction is a major source of pain for a lot of people.

Startle reflex, dark areas and depression

Depressed clients frequently mention to experience "dark phenomena" and are convinced that these relate to their mood disorder. These areas of darkness are explored by Beenhakker (2016), Manea & Beenhakker (2017) and Derks (2018) and they tend to disappear after treatment. The shapes and locations of such areas of darkness vary widely, from balls inside the body, or partly in the body, to clouds or veils at several meters distance. Derks (2016) hypothesized this darkness is an epiphenomenon of repressing a too hard-to-handle-life-issue. In therapeutic practice and clinical experiments, a lot of conformation was found for this idea (Beenhakker, 2016). More work is under investigation. Areas of darkness that appear close to the body imply that peripersonal neurons may be involved in the affliction. In faraway clouds this may be less the case. Also, these constant dark/ grey/ black formations give a sense of permanency to a depressed state, but

seem not to cause any type of startle, moreover they create a constant nuisance, by impairing the clear/ bright/ colorful view on the world. Beside this degradation of sensory input, the ongoing repression of some hard-to-cope-with-issue depletes the inhibitory capacity of the prefrontal cortical lobes (Kikuchi et al., 2010), which causes fatigue, heaviness, sleeplessness and lack of concentration (Singer, 1990).

But still there is an intricate relationship between the startle reflex and the diagnosis of depression. In the general non-depressed population, individuals show a reduced blink (startle) response in reaction to pleasant stimuli, compared to neutral stimuli, and an augmented startle (blink) response during the perception of unpleasant stimuli (Vrana, Spence, & Lang, 1988). Blink (startle) responses have been frequently used to measure the physiological reactivity in patients with mood and anxiety disorders (Grillon & Baas, 2003; Lang & McTeague, 2008; Vaidyanathan, Patrick, & Cuthbert, 2009). People suffering from depression may miss the attenuation of the startle response to positive stimuli, or may even show an increased startle to positive stimuli. These results are somewhat mysterious: as if depressed people are shocked by something nice! The level of the startle response to positive stimuli seems to rise with the severity of the depression (Kaviani et al., 2004) or, moreover, whether the depression has recurred more often (Vaidyanathan et al., 2014). One thing is clear – the response is abnormal. Interpretations assume that depressed patients respond to pleasant stimuli as if it were aversive ones (Allen et al., 1999).

Is there a way to make sense out of the above, considering the activity of peripersonal neurons? The "Biblical neurons" in depressed people show a protective response against pleasant stimuli where normally there is no reason for alarm. So, there must be something happening in depressed people that prevents peripersonal neurons to habituate to positive stimuli. If depression affects the peripersonal radar system, the logical consequence is that either neurons remain at their baseline response or they even increase firing – which indeed are the two patterns seen in depressed people (see above). Thus, depressed people do not have well-functioning "Biblical neurons" so to speak – that is why they startle to any intrusion (even to apples) into peripersonal space. What could be the connection here?

Mental space psychology suggests one more mechanism that has not been considered so far: the responsivity of peripersonal neurons might differ depending on *where* the stimulus is presented in mental space – relative to *where* the dark areas of the depression are located. When the dark areas are due to permanent inhibitory activity – as these are required for repression – this may disrupt the habituation of peripersonal neurons. According to Sinclair (1982), inhibitory interneurons are part of all learning: they provide the "rest" to the synaptic links to be strengthened. The adjustment of the peripersonal response to harmless stimuli may be impaired by the depletion of the necessary inhibitory neurotransmitters. This might give one more reason for the difference in empirical results.

A pressing hypothesis about peripersonal neurons in Asperger

It is typical for mental space psychology to explain psychological phenomena from the insights in mental space. The authors worked several years on a spatial hypothesis about "Asperger autism", fascinated by the growing number of people that receives this psychiatric label (Derks, 2014). Characteristic for people diagnosed Asperger is that they tend to suffer most from other peoples' (parents, peers, colleagues) reactions to their "nerdiness" (Baron-Cohen S. et al., 1985). Only in cases a diagnosis helps the person to better understand their own typicalities and adjust their lives to that, and also helps them to better profit from their unique traits, such a diagnosis is not harmful (Frith, 1989; Appignanesi, 2018). Sheffer (2018) in her book, "Asperger's Children: The Origins of Autism in Nazi Vienna", talks about the gruesome background of the diagnosis in 1944.

Other criticism to the Asperger diagnosis led to the term "Autistic Spectrum" in the DSM-5. Still the authors prefer the "Empathic Spectrum" or even better the "Self-Other Spectrum" or, as we will see later, "Left-Right cognitive style spectrum".

For a useful diagnosis, the limited capacity to empathize, together with a high ability to deal with complex information (Colombi, Liebal, Tomasello, Young, Warneken & Rogers, 2009), should be made understandable. On the other hand, people that suffer from the opposite, hyper empathy, people who often show less skills in detailed complex cognitive tasks and who are often exploited because they care to much about others, can be helped to better understand themselves in the same way. For instance, their social panoramas tend to be filled with the images of people at very close distances, not leaving much room for themselves. In contrast, people with an Asperger diagnosis have a lot of free space around them in their social panorama's (being a yet untested, but testable hypothesis).

The major assumption in mental space psychology is that all cognition and experience happen in the space in and around the person: in mental space. For the mental spatial model of Asperger, we start with a theory about the areas where the two cortical hemispheres of the brain project their cognitive activity (Derks, 2016). It appears, when observing people with a typical pattern of activation (from hereon called "neurotypical"), that the area of space used by the left hemisphere is much smaller than the space used by the right hemisphere. These observations are based on non-verbal and verbal expressions: when people point and gesture at mental images and schemas during an interview (Tversky, 2012). In other words, the locations where thoughts are projected fill a discernable volume of space: most left hemispheric thinking happens in an area that is about 1 meter 50 centimeters wide, with a similar height and about 3 meters long, that stretches straight in front of the persons head, and it also includes the front of the head and the thought – the inner voice, but also toothache and headache are experienced in this zone. In brief, all cognitive "reasoning" and schematization happens in this area of space. A part of what is going on is auditory but most is visual and kinesthetic. This area contains the more intense, conscious, foreground cognition. The intensity of awareness in this volume of space is highest.

The area of space used by the right hemisphere is much larger and it surrounds and includes the space used by the left side. It can easily be 7 meters wide and stretch 20 meters forwards and 5 meters backwards and it includes the whole body. The right hemisphere produces the less conscious form of background cognition. The intensity of the concepts activated by the right hemisphere is much lower than those from the left side. The concepts are more general and interconnected, more "holistic" and "intuitive", and provide the background context to the left hemispheric thought in the foreground (Vermeulen, 2007).

The fascinating idea came up, after reading the literature and making personal observations, that the extended cognitive skills that many Asperger patients possess, result from them having a larger (up to a double) left hemispheric projection (thinking) area in their mental space. It may be 3 meters wide, 3 meters high and 6 meters long and including the better part of the body. Here we are mainly talking about the area of space in front of the person, in which they visualize, feel and speak of all manner of concepts while contemplating. The idea that this area of space is larger in people with Asperger arose from the logic that such a larger space enables more cognitive distinctions and helps to memorize a greater number of facts. Also, more concepts can be held simultaneously in attention and more complex cognitive structures can be conceived and overseen.

This double left hemispheric capabilities come however at a price: the area of space used by the right hemisphere is much smaller than in neuro-typical people. And it may be entirely absent, leaving the person with the qualities of cognition that belong to the left side of the brain. The idea is that such a person has in fact two neurologically identical left-like hemispheres: one on the left and one on the right. So, there is less capacity for the fainter, broader, background cognition. And all typical skills attributed to the right side of the brain will be less available, among them contextual background information and a host of socio-spatial cognition of the type that is seen in the social panorama.

Thus, the second part of this hypothesis is that some people have more of the left hemispheric thinking and others more of the right hemispheric thinking. In other words, one minority of people has two left side types of hemispheres and other minority two right side type of hemispheres: the majority of people are somewhere in between. McGilchrist (2009) suggests that the functional difference between the hemispheres may have to do with one hemisphere running more on serotonin and the other on dopamine. Genetical and nutritional and other influences during development may cause the "normal" skewed distribution of these neurotransmitter (receptors). And here we have it: a spectrum, from left braininess to right braininess – as this is also often used these days in popular psychology.

The question posed here is, does such a difference between left and right also include peripersonal neurons?

The logical prediction is that left hemispheric peripersonal neurons guard a closer area of space with more intensity than the right hemispheric cells do. Then also, the left hemispheric peripersonal neurons may be less tolerant to intrusions of the near space than the peripersonal neurons from the right side of the brain. Asperger diagnosed people, who will have more of the left hemispheric type of peripersonal neurons, according to this hypothesis, will show a stronger defense of their personal space than neurotypicals. Observations do show this behavior: Asperger are reputed for avoiding touch and disliking uncomfortable irritations/ sensations on the skin (like from woolen clothes). The opposite may also be true: people who are hyper-empathic, who have more right hemispheric functioning, will be more tolerant to closeness and touch.

A third part of this hypothesis is based on the idea that the social panorama, in the sense of being a 3-D map of the social world, depends for a large part on right hemispheric cognition: social relations and spatial orientation. And indeed, experiments with hemispheric shut down support this, as do observations from patients with right hemispheric aphasia (Flöel, Buyx, Breitenstein, Lohmann, & Knecht, 2005). The capacity to orient in space and in social life becomes reduced when the right side does not function properly.

A prediction that can be tested with the social panorama, and by using a similar format that was used in the "partners and ex-partners experiment" (see above), is that people with an Asperger-like cognitive style will keep the images of intimate others further away than neurotypical people. The reason is that these images are not held in the less conscious right hemispheric background, but more in the double left type of hemispheric foreground, where they compete with other foreground concepts. If indeed Asperger patients place social images further away and out of the center of attention, because this area is needed for "thinking", this supports the above. When Asperger patients place social images further outwards in their mental space, this also fits, according to some other piece of social panorama logic. Moreover, it is harder to empathize with distant social images (personifications). Since empathy demands the mental "traveling" towards to position of the image (personification) of the other with whom one empathizes. This takes more effort because of the longer distance in mental space to be bridged (Derks, 2006).

III. Discussion and conclusions

Mental space psychology promotes a three-dimensional view in the sciences of the mind. The major assumption is that all cognition is spatial in nature and that this includes many up to present less understood psychological phenomena. The ideal of a multidisciplinary psychology, in which subjectivity goes hand in hand with neuroscience and clinical psychology, seems at our doorstep. This goes at the cost of the level of specialization that is so common in current science. The first question is: *When we look at the psyche in this broad manner, do we then need to give up our cozy corners?*

Our brain constantly computes space. Peripersonal neurons provide a fascinating – well explored – option to tap in how the brain does some of this computing.

The starting point was cells with tactile receptive fields. They are spatial in nature and respond to the stimulation of the skin. However, soon we arrived at the mental radar system, where "Biblical neurons" intelligently compute what will trigger the alarm or not. The suggestion that cells alone can do all of this on their own is too simplistic. The response patterns are too intelligent for single cells: but peripersonal cells must be the core elements in protecting the body-space. Their responses can be highly sophisticated: interestingly, they may not only respond to stimulations of a certain body part, but also if the subject watches the tactile stimulation of the same part of someone else's body, like for instance that of the experimenter (Ishida et al., 2010). In such a case one must think of mirror neurons playing in, and these too need many neighbors to do their job. So, the second question is: *Is a model based on one type of neuron too simplistic?*

In this paper we used peripersonal neurons as our reference for understanding spatial cognitive phenomena, like depression, possession, intimacy, empathy and Asperger. Not only do these neurons respond to too close for comfort tactile stimuli, but also to visual and auditory stimuli. They increase their activity when something appears to be close to their receptive field. First, they give alarm, in the extreme they lead to a flinching or defensive movement.

Graziano (2018) describes, in a very personal account, the large social impact of when this mechanism is not working well: when the person regularly comes too close to others, and they do not feel that their personal space is respected. His son could not keep appropriate distance and ended up in trouble. Not only did he offend other people, his issue included the handling of any kind of tool – one simply has to have a concept of where objects are in relation to one's body. Graziano (2018) shares a compelling example of the importance of space in our daily life, which supports the focus of mental space psychology. The third question is: *Does the discovery of a neural/ spatial mechanism also open our eyes for new categories of problems?*

Mental space psychology taught us that changing the mental location of something (people, object, problems etc.) leads to a change in the emotional impact of that something, up to the point that this has a psychotherapeutic effect. Peripersonal neurons provide the neural mechanism for this – changing the location changes the neural response.

There exists some uncharted territory in relation to the role of peripersonal neurons. The hypothesis presented above about some personality characteristics in the autistic spectrum is an example: it makes several

behavioral typicalities more understandable. Another area that requires more explorations deals with forms of therapy that make use of touch or near touch: like Reiki, craniosacral therapy and the classical Mesmerian passes/ strokes in magnetization. Many psychologists regard these methods as suggestive/ superstitious/ esoteric/ placebo, because the body is not really touched. However, on the base of our knowledge about peripersonal neurons, "nearly touching" must have a clear impact on the central nervous system. When such methods show therapeutic effect, this may as well be explained from the activation of the immune system over peripersonal neurons.

The fourth question is: *Is communication with near-touch a normal part of the human therapeutic arsenal?*

Psychological problems may change the responsiveness of peripersonal neurons. If one uses the startle reflex as example, there is some empirical evidence for this.

It is interesting and not entirely explained that the response changes with the valence of the object. If the monkey wants to have the apple in the receptive field, no alarm is given. If we have negative emotions toward a person, we shy away – if we love a person, we let him/ her come close. Graziano (2018) wonders about how sex is at all possible considering peripersonal neurons.

When exploring the spatial side of the experience of being in love, Derks & Raz (2017) noticed what they called a "pink cloud" in mental space. This "pink cloud", "pink bubble" or the connected "rose colored glasses" are ubiquitous in everyday speech or lyrics, but not in science. Falling in love may be the necessary process to habituate the peripersonal defense-system to let someone "in". On the neuro-scientific side, when looking at loved persons the reward centers of the brain are active, while areas connected with fear and criticism become inactive (Bartels & Zeki, 2000). Thus, activation of pleasurable things like reward and deactivation of fear related responses seems to override the defensive reaction of peripersonal neurons. This pattern is similar to the reaction of "Biblical neurons" for pleasant stimuli. Neurotransmitters seem to play an important role: dopamine levels increase, while serotonin levels decrease (Cacioppo et al., 2012). This opens a whole field of research into the role of neurotransmitters for mental space. The mystery of peripersonal neurons is quite complex. This type of processing is very deep and automatic – it even works in anaesthetized monkeys! It is thus not a cognitive procedure. This confirms the importance of spatial processing as postulated by mental space psychology.

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