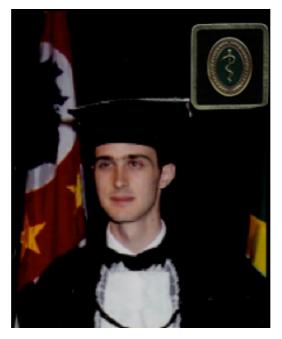**Chapter 4**

Multimodal Processing of Spatial Information: The Integrative Role of Posterior Parietal Cortex and related Clinical Syndromes

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ABSTRACT

Spatial cognition corresponds to the individual's capacity to perceive the spatial relationship among objects and dealing with the notions of deepness, solidity and distance. This cognitive ability is intimately linked to spatial perception which can be understood as the final product of integrative processes organizing sensorial stimuli in order to present to consciousness a general overview about forms and spatial relationships of external objects. Although many studies focus in cortical process related to spatial cognition, there are few descriptions in the literature about the different sensorial routes which are capable to provide elements for generation of spatial cognition. In this article we provide a critical literature review of sensory afferent stimuli (mainly visual, tactile, proprioceptive, auditive and vestibular) as well as cognitive mechanisms involved in this process. We also discuss the importance of the Multimodal Association Area of the Posterior Parietal Cortex to spatial cognition emphasizing some of the

possible disturbs generated by lesions in this area.

INTRODUCTION

Spatial cognition corresponds to the individual's capacity to perceive the spatial relationship among objects and dealing with the notions of deepness, solidity and distance. The spatial cognition is a type of intellectual ability derived from the spatial perception. This can be understood as the final product organization and integration of the sensorial stimulation to give a relatively faithful and embracing overview of the specialty, and, of certain way, of the geometry of the external world.

SENSORIAL ROUTES

The great mathematician and philosopher of the XIX century Henry Poincarè used to say that there are sensations that are not followed of a "direction feeling". Such are, for example, the proprioceptive and visual sensations. Other sensations, in contrast, such as the gustatory and olfactory, would not be followed by this "feeling".

Amongst the diverse sensorial routes capable to give elements for spatial cognition we can cite: the visual system, the tactile system, the proprioceptive system, the auditory system and the vestibular system. To follow we will explain how the sensorial information transmitted for each one of the cited routes above can contribute for the generation of the spatial cognition.

1. Vision

The base of the spatial perception supplied for the vision is contained in the form (dimensions) of the objects and in the relations of these (for example: superior, inferior, closer, far) between itself and with the individual. The rays of light that happen over the object will be projected on different points of the retina,

stimulating the specific receptors. The formed images will represent, therefore, the complex geometric relationships between the objects which originated them. This will allow the individual to situate the different objects on the space, as well as its own body in relation of these.

Once the projected image on the retina is two-dimensional, an infinite number of different three-dimensional spatial combinations will produce the same standard of stimulation of the retina. So appears the question about how would be possible to distinguish between those different images. As a plain screen, two-dimensional, the retina would be capable to represent two of the three spatial dimensions, losing in this process, essential information of the perfect spatial reproduction of the external objects.

However, it must be remembered there are two interconnected perceptive devices (in this case, the two eyes) on which the same image is represented of lightly different ways. Then the brain can extract, through the comparison of these images, important information concerning the relations of deepness between the objects, function called stereopsy.

In this way the binocular vision allow a three-dimensional perception, which would be possible with a monocular vision. Proof of that is the extreme difficulty on the part of the individual that had lost the vision of one of the eyes in perceives the deepness and distance notion. Several tests, like the randomized points stereograms, can be used for the detection of such kind of defect.

2. Proprioception and Vestibular Information

Proprioception and vestibular information contributes for the formation of the spatial cognition on indirect way. They supply information about the spatial position of several parts of the body. With that it is possible to determinate the angulations between those parts, being possible to abstract geometric relations from those information.

The capacity to know the exact localization of parts of the own body in the space without the use of the vision is called proprioception or position sense. This ability is based on information proceeding from the Golgi tendinous organs in the articulations. To test it that is possible, for example, to request the individual to draw on a sheet of paper the

figure formed for its own torso and members. This person will draw something similar to a star, if its both arms will be in the horizontal line, its head extended and its legs lightly in abduction position. Thus several other figures would be formed in case of its arms were extended or flexed, up or down.

This function to correlate proprioceptive and vestibular information in order to generate a positional referential centered on the individual's body is realized by some specific neurons of the posterior parietal cortex (more specifically, by neurons of the LIP area- lateral intraparietal area).

3. Touch

In case of touch, the sensorial information is integrated in the right parietal cortex in order to allow the person to recognize an object by its "form". The capacity is called stereognosia. It is possible to test this ability on the following way: it is placed a key on the individual's hand with closed eyes and it is requested that the individual identify the object. Patients with right parietal injuries are incapable to recognize the object through the touch, although to get to make it

through other sensorial ways as the vision, for example.

4. Audition

The perception of the spatial direction through the audition involves peculiar mechanisms, although to present some similarity with the vision. In analogy to the binocular disparity, also the two ears receive on different ways the pressure waves derived from the emitting sources of sound. Those waves reach the ear that is closer some milliseconds before reaching the other ear. This disparity, in set with other binocular differences (as the fact that the most distant ear receives the stimulation in a slightly lower intensity due to a species of "acoustic shade" resultant of the barrage of the sonorous waves by the head) allows the watcher to locate the direction and the origin of the sound.

POSTERIOR PARIETAL CORTEX – A MULTIMODAL ASSOCIATION AREA

The posterior parietal cortex – specifically the right hemisphere (7, 39 and 40 Brodmann's areas) is responsible for multimodal interactions related to spatial perception, this area is also

responsible for the spatial aiming of the attention, as well as for the integration of the motor system (praxis) with the spatial perceptions, in order to organize the individual's motor plains.

Images of functional magnetic resonance showed that the part of the posterior parietal cortex critical for the spatial attention is in the intraparietal region. When this area is injured, the modality-specific channel of information related to the external space can remain intact, but cannot be recombined to generate an interactive and coherent representation necessary to the adaptive development of the spatial cognition.

The posterior parietal cortex must not be understood as a center that contains a map, but as a critical sluice that opens access to spatial representations proceeding from several cerebral areas and related to the attention and exploration of the external space. There are some specific neuronal groups in this region (specifically form the 7th and LIP area) whose function seems to be to represent the extra corporal space of the exterior space in a useful way, looking the plans and subsequent motor tasks. Those neurons are capable to combine the information proceeding from the retina

with information about the position of the eyes and fit them on a perceptive set whose center is occupied by the individual's head. This way, all the visual information would be perceived in function of this reference point. The conclusions of the studies suggest that one of the functions of the LIP area is the integration of the auditive, visual, tactile and proprioceptive information on a holistic set, in order to supply a combined and only sense of spatial dimension.

SPATIAL COGNITION DISTURBS

We will present to follow some disturbs related to the deficit in the spatial cognition or on the use of that as an aid to some other superior function (language, spatial orientation, attention orientation, etc.). The accurate correlation between each one of those syndromes and the subjacent anatomic injury is usually not possible, due to significant anatomic variability of neural structures among different individuals, which makes difficult to determinate specific neuronal groups compromised by determined injury.

Therefore, in general terms, we can just affirm that those disturbs are some how correlated to the injuries on the

multimodal association area of the posterior parietal cortex and its connections.

1. Syndromes of the Parietal Lobe

Injuries of the posterior parietal cortex on the right hemisphere, mainly of the inferior parietal lobule lead to deficits on tasks of spatial attention, visual – spatial integration and draw (construction). It is called "syndrome of the parietal lobe". Patients with that disturb fail on tests of "mental rotation" and they are not capable to identify objects seen from and uncommon perspective. Other components of the right parietal syndrome are: "anosognosia" (refusal of the disease), "dressing apraxia, constructive apraxia, confusional states, deficits of localization of routes or pathways and disturbs related to the "corporal navigation" in reference to solid objects like chairs and beds.

2. Defect on the Geographic Orientation

This disturb is characterized by the incapacity to identify localities on a map or to build a map of a city or a country. It is present in patients with posterior parietal occipital injuries. *Kanwisher*, using studies

of functional magnetic resonance (fMRI) located an area in the parahipocampal cortex (commonly referred to as Parahipocampal Place Area - PPA that is involved specifically on the perception of the visual local environment, an essential component on the "navigation". Information about the "layout" of the local space produces activation of this area. Those authors proposed that PPA might encode geometry of the local environment in such a way that the functional and anatomic integrity of this area, as well as its routes of connection with the posterior parietal area, would be essential to geographic orientation.

3. Simultanagnosia (visual disorientation)

Simultanagnosia can be defined as the incapacity to perceive the visual field as a whole, what results in perception and recognition of only parts of that field. It is one of the three components of the Balint's Syndrome (a complex disturb of the spatial analysis – figure 1). The other two components of this syndrome are: the optics ataxia (a disturb of the act to point a target under the orientation of the vision) and the ocular apraxia (incapacity to direct visual attention towards a new stimulus).

Figure 1. Image of computed tomography (CT) of a patient with Balint's Syndrome caused by a meningioma. Perceive that the injury involves areas functionally important of the right posterior parietal region.

The essence of the simultanagnosia is subjective. The patient with simultanagnosia is incapable to catch the visual field as a whole. A species of comminution of the visual field occurs. Normally those functional fragment of the visual field corresponds to a representation of the macula that moves on a random way from quadrant to quadrant. As a result of that, a clearly visible object on a given moment can suddenly disappear as the visual fixation changes. The simultanagnosia can appear after injuries on the posterior occipital-parietal region on both sides.

4. Disturbs of Constructive ability (constructive apraxia)

The patients with constructive apraxia have a normal visual acuity, normal perception of the objects and of their spatial relations and adequate motor ability. However, they are incapable to use

the visual information to copy forms and to draw objects (such as a house, a clock or a face). The sub-test of blocks of the "Wechsler Adult Intelligence Scale – WAIS" is ordinarily used to test the construction abilities.

That disturb occurs mainly as a result of wide right parietal injuries.

5. Disturb of the Ability to Dress (dress apraxia)

The dress apraxia corresponds to a defect on the sensorial feedback of the parts of the body back to the right parietal cortex. The person becomes incapable to align the member of the body with the vestment.

It can result from an injury on the right parietal cortex or also can come from other syndromes, as simultanagnosia or optics ataxia. This disturb is deeply associated to injuries of neurons of the 7th and LIP area, which, as showed previously, have the function to represent the extra-corporeal space of the external world on a useful way aiming the subsequent motor plains and tasks.

6. Heminegligence Syndrome

This syndrome is characterized by a state of indifference in relation to the

sensorial stimulus proceeding from the patient's left side, as well as reduction on motor activities to be executed in this region. On grave cases, the patient bears as if the left half of the universe does not exit anymore. The patient dresses, washes and shaves just the right side, eats just the right side of the food on the plate and, when solicited, copies just the right half of the presented draws (figure 2).

Figure 2. Image of a patient's notebook with heminegligence syndrome. We can perceive the ignorance in relation to any element situated on the patient's experiential left field.

This syndrome seems to be a result of the injury of the parietal component of more general system responsible by the spatial attention formed by the cingulated girus, frontal visual area, thalamus, striatum and superior colliculus, as well as of parts of the limbic system, related to the mood and motivation.

7. Williams' Syndrome

The Williams' Syndrome is a rare pathology, of hereditary nature, caused by the deletion of the gene of elastin and

adjacent regions on the 7q11 chromosome. Individuals carrying the Williams' Syndrome present, besides cardiovascular and conjunctive tissue deficits, congenital deficits on cognitive abilities in visual and spatial order, with preserved cognitive capacity on tasks that involves linguistics abilities.

Even on verbal tasks, individuals with Williams' Syndrome present serious problems when they witness propositions that contain some element of spatial or directional character. Those individual present important difficulty to execute tasks that involve some type of visual-spatial construction, such as draws and design of blocks. The results of the research suggest that this difficulty involves the visual-spatial construction itself, and do not involves the spatial perception in general, since individuals carrying the Williams' Syndrome present, for example, ability to recognize preserved faces.

Studies with Functional Magnetic Resonance (fMRI) demonstrated that those patients showed specific deficits on the activity of the cortex that compose the Dorsal Route (way of the "where", related to the spatial localization), composed by neurons that connect the areas of visual

unimodal association with the parietal and frontal cortex, with relative preservation of the Ventral Route (way of the "what", related to the identification of objects), which connect the primary visual areas to the cortex of temporal visual association and limbic areas.

CONCLUSION

It was possible along this exposition perceive that, despite of the unarguable preponderance of the visual information, several are the sensorial inputs that contribute, each one by a singular way, for this complex and rich ability called spatial cognition.

It was also demonstrated the intimate correlation between multimodal association areas of the posterior parietal cortex and spatial cognition through a short description of some of possible disturbs derived from anatomic injuries on this region.

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