UNIVERSITY OF BERGAMO
Faculty of Education Sciences
PhD Course in Clinical Psychology

MODULATION OF VISUO-SPATIAL ATTENTION BY MEANS OF EMOTIONAL FACIAL AND BODILY EXPRESSIONS: THEORETICAL BASIS AND EMPIRICAL EVIDENCE

Phd Coordinator:
Prof. Valeria UGAZIO

Tutor:
Prof. Maria Luisa RUSCONI

Phd Candidate: Laura CARELLI
Registration number: 1004369

XXIII DOCTORAL CYCLE - 2008-2010

TABLE OF CONTENTS

Chapter 5

INTRODUCTION

The present research was aimed at investigating how visuo-spatial attention in a line bisection task can be modulated by means of expressions of emotions. In particular, we have investigated these aspects in a sample of unilateral spatial neglect (USN) patients, in order to obtain, according to previous studies, a deeper insight into the implicit detection and recognition of meaningful emotional expressions.

In the first chapter, neural basis of USN have been described, according to the available literature, and the main theories for the interpretation of this syndrome have been shortly discussed. Main clinical manifestations of neglect have been described, together to some neuropsychologycal tests employed in order to evaluate the patient's impairment in exploring space and some important rehabilitation interventions. Finally, some issues, relevant to this study, concerning the dissociation between implicit and explicit recognition of neglected stimuli have been proposed, according to studies showing that patients with USN are able to process neglected stimuli, up to extract their meaning.

In the second chapter, an overview about the field of emotions and brain has been provided. A short description of the principal theories explaining emotions has been proposed, with particular reference to the psycho-evolutionary theory of emotions. Then, the neurophysiologycal basis of emotion have been presented, according to traditional and recent studies about cerebral regions playing a role in those processes, including both subcortical and cortical areas. Finally, the processes underlying the recognition of emotional significance of an event and the evaluation of the emotional meaning of an expression have been reported.

The third chapter addresses the relationship between emotions and neglect, according to the results of the recent literature available in this field of research.

Main studies has been presented, showing how attention can be captured by means of meaningful emotional stimuli, by providing evidences both in normal subjects and brain damaged patients (mainly represented by unilateral spatial neglect and cortical blind patients). Principal results of studies employing facial expressions as emotional cueing have been reported, followed by the description of causal interactions between different brain regions related to the modulation of visual processing by attention and emotion. Finally, recent insight about similarity and differences between facial and bodily expressions in modulating spatial attention has been discussed, according to de Gelder and colleagues studies.

The fourth chapter describes the research, aimed at investigating how visuo-spatial attention in a line bisection task can be modulated by means of emotional expressions. In particular, we investigated these aspects in a sample of unilateral spatial neglect (USN) patients and a healthy participant's group. Our objectives were to clarify if a prevalent role is present for negative emotions, with respect to positive ones, in summoning spatial attention, since not unique results have been provided into literature. We also wanted to specifically verify whether facial expressions can more easily involve spatial attention if presented in a peripersonal space and bodily ones in an extrapersonal space, according to the different perceptual characteristics of those stimuli. This aspect is suitable to be studied in spatial neglect, since a dissociation between near and far space can be observed in those patients, with selective impaired performances for one of the two spatial region. In such frame, we aimed to prove that faces and bodies differently modulate spatial attention, according to the specific portion of space involved in spatial neglect (peripersonal or extrapersonal).

In this chapter, the experimental design has been described; it has been developed and implemented, in order to separately study the role played by emotions expressed by faces and bodies, according to the distance from which they are presented ("near" or "peripersonal" and "far" or "extrapersonal" space) and the content of the emotional stimuli, that is happy or fearful versus neutral expressions. Statistical analysis and main results has been presented and discussed.

In the last chapter, discussion of the obtained results and conclusions are provided.

CHAPTER 1

VISUAL ATTENTION TO SPATIAL LOCATIONS UNDER NORMAL AND PATHOLOGICAL CONDITIONS

1.1 What is (visual) attention?

The term “attention” apparently refers to something similar to sensation and perception, as in our common language we use this expression to describe experiences like “a children who pays attention to what his/her mother says”. However, a main distinction regards the introspective component of attention, i.e.. is the capability to pay attention to things other than sensory input, such as internal processes.

William James (1890) said that “everybody knows what attention is” and he was interested in the “expectant attention”, or in the attention function of selection. He used terms like “anticipatory thinking”, “ideational preparation” and “anticipatory imagination” in describing his concept of attention (James, 1890). Another description of attention was given by Von Helmholtz in 1894 (Von Helmholtz, *Physiologiske Optik* (Physiological Optics), p.741, quoted in James, 1890/1950, p.438) who said that “one can concentrate attention”, considering attention as a kind of “force” that can be moved through space in order to enhance perception in the regions of interest. So, attention as a force is viewed as essential for visual perception.

Also Wundt, in 1874, described attention as an “inner activity” determining the degree of presence of ideas in consciousness.

More recently, psychologists have characterized visual attention by using a number of metaphors like “a filter” (Broadbent, 1958), “effort” (Kahnemann, 1973), “resources” (e.g., Shaw & Shaw, 1978), “a control process of short term-memory” (Shifrin & Schneider, 1977), “orienting” (Posner, 1980), “conjoining object features” (Treisman & Gelade, 1980), “a gate” (Reeves & Sperling, 1986), and both “a selective channel” and “a preparatory activity distribution” (LaBerge & Brown, 1989).

These metaphors can be grouped into two main categories: the first one proposes that attention enhances the flow of information in the selected area, while the second category suggests just the opposite, that attention inhibits the information flow in the surround.

Well then, what actually is “attention”? For sure, we can think at Attention as not the work of a single centre, but as the result of the coordinated activity of several neuronal networks

(Rizzolatti, Gentilucci & Matelli, 1985).

These networks are composed by several cortical areas working simultaneously, for example in visual attention, as when a person looks at a daisy: the cortical area V4 (or “color area”) is activated, and since the flower location is also encoded, the dorsolateral prefrontal cortex and posterior parietal cortex are also activated. Attending to this particular flower makes the attention to enhance activity in the attended set of pathways relative to the activity in the unattended set of pathways. Besides, an activation of the anterior cortical areas that serve working memory for the location of the flower is also present.

1.2 Theoretical models of attention

When we define attention as a cerebral cognitive mechanism, allowing to process relevant input, thoughts or actions and, at the same time, to ignore irrelevant ones, we describe the principal characteristics of selective attention.

A first main distinction can be made between a passive non-voluntary attention and an active voluntary attention. These two focused modes of attention have also been called *automatic* allocation of attention and *voluntary* allocation of attention (Yantis & Jonides, 1984), or *exogenous* control of attention and *endogenous* control of attention (Posner, 1980).

The voluntary orientation of attention refers to the capacity to intentionally pay attention to something, while automatic attention refers to those situations when some aspects of sensory experience catch our attention.

In 1894 Helmann von Helmholtz performed an experiment about sensory attention, and discovered another characteristic of this phenomenon, which has been lately named “covert attention”; this is the capacity to focus attention on sensations located in a specific part of the peripheral nervous system, and simultaneously to exclude attention toward other parts, without performing ocular movements or accommodation changes.

The selective function of visual attention is concerned with selecting the relevant stimuli from the visual field relevant to the person, because the visual system in humans has a limited capacity, so that it can not possibly analyse all the visual stimuli at once. This limited capacity of the visual system has been demonstrated by many researchers (see for example Duncan, 1980). Broadbent (1958), who defined attention as a “filter”, developed a model in order to describe the mechanism underlying limitations in attentional capacity: in this model, a gating process limits the amount of information which can pass to a higher order elaboration, with a “top-down” control mechanism, regulated by voluntary executive processes.

This limited capacity of visual attention has lead to the elaboration of two different hypothesis, with regard to the stage of processing, initial or more advanced, of signals entering the sensory system.

The early selection theory sustains that only individual physical characteristics of the stimulus (eg, orientation and color) can be processed without the involvement of selective attention (preattentively). Consequently, attention would act as a peripheral filter, that excludes from the processing the most information about the stimulus, except those most basic, that are processed without attention (Treisman, 1988).

The second hypothesis states that all the features of the stimulus should be processed without attention, and therefore can be recognized and identified without the aid of selective attention, which instead would act late in the process, i.e.. during the selection of the response (Posner and Snyder, 1975).

The latter hypothesis can explain why some significant stimuli, as our name, are processed even if not attended (see, for example, Mack & Rock, 1998).

Two experimental paradigms have contributed to the understanding of spatial attention: the visual search paradigm and the spatial cueing paradigm.

Visual search tasks require the subject to look for a visual target among distractors (with an ecological example, finding a friend’s face in a crowded room). In a typical visual search task, the number of distractors is varied across trials, and reaction time (RT) is measured as a function of the set size.

A standard demonstration of attentional limited capacity is to increase the number of distractors beside the target in a visual search task. The relationship between the time it takes the subject to report the presence or absence of the target and the number of distractor elements is considered to be the indicator of whether the target stimulus is processed without attention. If the time to report the presence of the target increases as the number of distractors increases, the stimulus is said to require focused attentional processing (see, for example, Treisman & Gelade, 1980). If, in trials where a target is present, an increase in the number of distractor elements does not cause corresponding increase in the time it takes to report the target, it is said that the target stimulus is processed "preattentively" (without attention). In these cases, it is said that the target "pops out", then it would seem that its perception does not require a serial search through each item in the array.

Targets "pop out" differ from distractors for a single aspect (for example, a letter written in a different colour), so the subject does not need to explore the whole screen in order to find the target. On the contrary, targets processed with a serial search share with the distractors one or more characteristics (for example, a red circle among distractors consisting of both red X and circle or X of different colours) (see Fig.1.1).

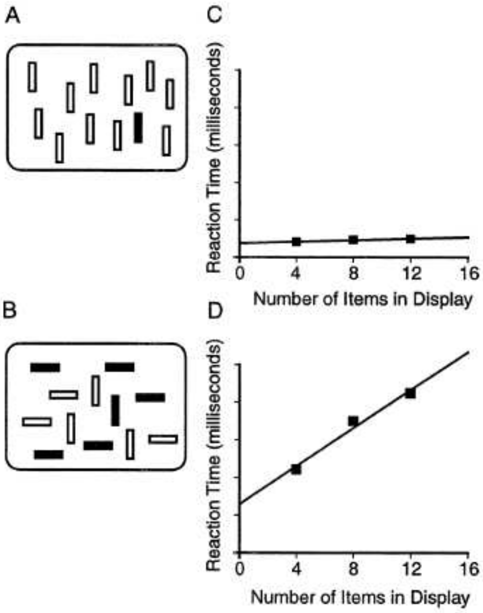


Fig. 1.1 A visual search task where the targets differ from the distractors by a single feature, ie colour (A); a visual search task where the targets differ from the distractors by a conjunction of features, ie color and orientation (B); typical results for a visual search task as showed in A: adding additional distractors doesn't increase the time to search through the display, showing a parallel search (C); typical results for a visual search task as B: adding distractors increases the time to search through the display, showing a serial search (D).

However, these two systems, attentive and pre-attentive, are so closely coordinated, that in an evolutionary perspective is supposed to help the visual perception of natural environments, by allowing the preattentive visual system to cause attentional shifts to conspicuous elements from the visual field (Miller, 1989; Muller & Rabbitt, 1989).

On the other side, spatial cueing paradigm tipically consists of placing a stimulus or instruction that precedes a target stimulus to be detected. This stimulus or instruction is referred to as the "cue", and it either predicts the target's location or does not predict the target's location. In Posner's widely used task, depicted in Fig. 1.2, each trial begins with a cue intended to orient an observer's attention to one of several locations. The cue can be a peripheral flicker (Fig. 1.2a) at the location where a target may appear or a centrally presented symbol, such as an arrow (Fig. 1.2b), that points to the location where a target may appear. After a delay, a target is presented and the observer must indicate that he/she has detected the target (for example, by pressing a button as soon as the target appears) or discriminates among several targets.

With the name of “valid” trials, are indicated those trials where the cue correctly predicts the target’s location, while in “invalid” trials the cue is misleading. Some experiments also include neutral trials that provide no information about the target’s location. Observers typically respond fastest to valid trials and slowest to invalid trials, and this difference can be referred to as a ‘‘validity effect’’ (Fig. 1.2c).

After about 300 ms, RT to detect a target is longer when a target appears at the valid location compared with the invalid location; in other words, facilitation is transformed into inhibition. This phenomenon is termed inhibition of return (IOR). It has been suggested that IOR is a mechanism whereby the attentional system favors novel spatial locations by inhibiting already scanned ones (Klein, 2004; Posner, 1985).

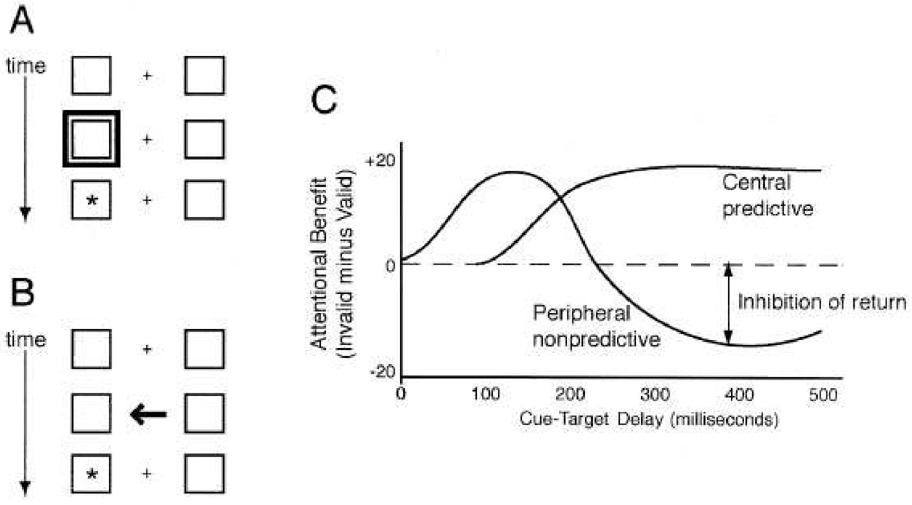


Fig. 1.2 Posner’s spatial cueing task. Observers are asked to detect the appearance of a target that has been validly or invalidly precued. (A) Peripheral precue that automatically summons spatial attention to the cued region. (B) Central, symbolic precue that can be used to voluntarily shift spatial attention to the cued region. (C) Typical results from spatial cuing studies. The graph plots the difference between response times to invalid and valid trials. Nonpredictive peripheral precues, in which valid and invalid trials are equally likely, result in attentional benefits initially, followed by a period of inhibition termed ‘‘inhibition of return’’ (IoR). Predictive central precues require more time to produce an attentional benefit, and these cues may not produce IoR in some circumstances

1.3 Mechanisms of attentional control

Attentional control is influenced by different parameters. Two general classes of control are top-down sources, which arise from the current behavioral goals, and bottom-up sources, which arise from sensory stimuli present in a scene. These two sources can be illustrated with reference to the visual search task. In the previously described visual search task, participants are required to search for a particular target, with specific visual characteristics, that will appear among other distractors (see Fig. 1.1). The target characteristics, its visual description, are temporarily stored in visual memory in order to perform the task. This memory trace, which can be named as a “template”, influences visual search in a top-down manner, since observers actively search for these specific characteristics. On the other side, the actual scene which is presented in the display provides the bottom-up information, indicating where objects are located and which features (eg, color, orientation, shape, and so forth) are present at each location. In order to perform the visual search task, the observer has to find a balance between the top-down and bottom-up information.

These two dimensions of spatial attention control, bottom-up and top-down, can also be examined using spatial cueing tasks, where attention is directed to a location before a target appears. The type of spatial cue can modulate attentional control, by favoring bottom-up factors or top-down factors. For example, peripheral cues that involve an abrupt luminance change (eg, a flicker in the visual periphery) automatically attract attention via bottom-up control parameters, regardless of the observer’s intentions. In contrast, central, symbolic cues orient attention only if the observer voluntarily interprets the cue and shifts attention accordingly. The latter, being dependent on task-related goals and observers’ expectancies, involve top-down control processes. As in visual search, the control of attention in spatial cueing tasks involves a balance between bottom-up and top-down factors. So, bottom-up peripheral cues capture attention, even if they may be influenced by expectations of where the target will appear (top-down processes).

Automatic processes differ from voluntary ones in terms of speed of execution. It has been demonstrated by manipulating the possibility to predict the position of targets: subjects were instructed, in one case, to wait for the target in a specific position, and, in the other case, that the target could appear in a random location in the screen (Wolfe, 2000).

What researchers observed was that the time needed to find the target was inferior when subjects searched for it by using ongoing sensory information, with respect to when voluntarily modulated their focus of attention.

This result suggests that our brain explores the visual world in an automatic way, by using a speed and effective reflector.

1.4 Neural systems for spatial attention

In order to describe the neural mechanism underlying the attentional selection in human beings, researchers employ different methods, such as the electrical cerebral activity recording and neuroimaging techniques.

In particular, ERP (event-related potential) consist of the recording of cerebral waves evoked by a specific event detection, which usually corresponds to a target stimulus. Neuroimaging methods employed mainly consist of fMRI (functional Magnetic Resonance Imaging) and PET (Positron Emission Tomography).

In the next paragraphs, results of some important studies investigating visual attention by mean of ERP, fMRI and PET are described.

1.4.1 Electrophysiology of visual attention: ERP investigation

In visual ERP studies, the electrical activity generated by cerebral neurons, sensitive to visual stimuli, is directly recorded, in order to identify the stages in the elaboration process influenced by visual attention.

Robert Eason and coll. (1969) first showed that during visuo-spatial attention (selective for spatial location), some ERPs showed a change in their amplitude. Other studies proved that this modulation started about 70 ms after the visual stimulus appeared.

In these experiments, participants were verbally instructed to pay covert attention toward a certain spatial location (for example, the right hemispace), and to ignore stimuli coming from other locations (for example, left hemispace). Then, the response to identical stimuli in the two conditions (of covert attention or when stimuli was ignored) was compared: when attention was voluntarily focused, from 70 ms after stimulus appearance an increase in the amplitude was recorded over the posterior controlateral (occipital) region in the scalp. This first big positive wave, named P1, had a larger amplitude with respect to the condition when attention was focused in other regions of space.

These results prove that visuo-spatial attention modulates the elaboration in the visual cortex, in particular in extra-striate areas. An important question is whether similar neural mechanism operates even when attention is automatically attracted, through reflexive processes, toward certain spatial locations. In other words, if when a sensory event captures in an automatic way our attention toward a certain location of the visual field, an increase in the neural elaboration in the visual cortex is observable.

Studies based on the automatic cueing showed that, when a target appears just after a sensory cue located in the same position, the occipital wave P1 is larger with respect to when cue and target stimulus appear in different positions.

These results support the idea that both voluntary (top-down) and automatic (bottom-up) attentions are based on mechanisms which are similar, with regard to the effect observed in the initial stages of cortical elaboration.

1.4.2. Functional neuroimaging of visual attention: fMRI and PET studies

Brain imaging methods allow measuring the physiological correlates of brain activity in human subjects while performing cognitive tasks. In particular, fMRI and PET have been employed in order to investigate the functional anatomy of high order cognitive functions.

In PET studies, Corbetta and coll. (1991) found that attention for basic stimuli characteristics, such as colour, shape and movement, tipically causes an increase in blood circulation in the extrastriate visual cortex. These areas were selectively modulated when visual attention was focused (due to a verbal instruction) on the correspondent stimulus characteristics (selective attention for characteristics). In particular, attention to shape caused a bilateral activation in fusiform gyrus, parahippocampal gyrus, collateral sulcus in left hemisphere, the right superior temporal sulcus (STS) and a region between the calcarin scissure and the parietal-occipital sulcus (POS) in right hemisphere. The selective attention to movement (speed) activated the left parahippocampal gyrus, the right superior temporal sulcus (in a region different from that associated to attention for shape), and the left inferior parietal lobule.

Hans-Jochen Heinze and coll. (1997; 2000) performed relevant studies on spatial selective attention, by demonstrating that the attention focused on a certain spatial location lead to activation in the posterior fusiform gyrus.

In addition to cortical areas specific to certain sensory modalities, PET and fMRI studies on selective attention revealed attention-related activities in other regions: thalamus (probably, only the pulvinar nucleus), basal ganglia, the insular cortex, the frontal cortex, the anterior cingulus gyrus, the parietal posterior cortex and temporal lobe. Some of these regions, such as the frontal cortex, the parietal cortex and the pulvinar, are involved in orienting attention according to the task to be performed.

Corbetta et al. (1993) found that the blood circulation in the parietal posterior cortex increases when attention is moved from a spatial location to another, in order to find a target stimulus. The same cerebral area is activated when attention moves across the visual field during a visual search. These results prove an important role for posterior parietal lobes in spatial attention.

Joseph Hopfinger and coll. (2000) have studied the cerebral circuit which is involved in the control of spatial attention. In order to do this, they employed a spatial cueing paradigm, with bilateral stimuli and a cue, indicating the side where subjects had to pay attention.

Thanks to event-related fMRI study during task execution, a top down network of attentional control, composed by the superior frontal cortex, the inferior parietal cortex, the superior temporal cortex and parts of posterior cingulus gyrus and insular cortex, was highlighted; the activations in these areas caused an activation in visual cortex, controlateral to the hemispace where attention was directed. This study demonstrated (as already described with regard to ERP studies) that top-down attentional processes influence the visual cortex, before the appearance of the targets relevant for the task. In fact, activations in visual area involved in the target elaboration have been observed in the temporal interval after the cue presentation and before the target appearance. This kind of "start-up" in sensory cortex due to attentional modulation could serve for preparing the successive selective elaboration of stimuli.

1.4.3. Subcortical modulation of attentional processes

Studies performed on monkeys showed a role for superior colliculus in attentional processes. Robert Wurtz and coll., in the seventies, found that some neurons in the colliculus were activated when animals performed saccadic ocular movements toward target stimuli. These activations were not present when ocular movements where not performed, nor when ocular movements were directed toward other regions of space (and not toward the target stimuli). They concluded that those neurons were not directly involved in voluntary visual selective attention processes, but rather they participate in a system controlling ocular movements; so, they can play a role in overt orienting of visual attention, but not in covert orienting. Recent findings provide evidences for a role of superior colliculus also in attentional processes not involving ocular movements, even if much investigation is needed to specify the neural mechanisms underlying these processes.

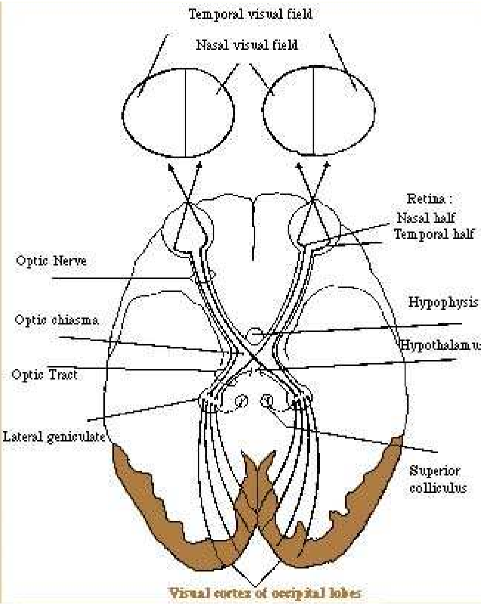


Fig.1.3 The superior colliculus, a midbrain structure that is between the eyes and the occipital lobe along the optical pathway, also plays a role in spatial attention.

Another subcortical structure which has been studied with regard to attention is the pulvinar, a thalamic nuclei with interconnections to frontal, parietal, occipital and temporal cortical areas. Pulvinar nucleus is also connected to amygdala, suggesting a role in the detection of threat-related stimuli (this aspect will be discussed in chapter 2 and 3).

According to neurophysiological studies performed in monkeys and functional imaging studies in humans, the thalamic pulvinar seems to play a role in attentional processes, such as filtering, selective processing of salient or behaviourally important stimuli and active visual scanning (in Karnath et al., 2001).

Karnath et al. (2001) analyzed the anatomical correlates of spatial neglect (a well studied disorder of spatial attention, which will be described in the next paragraphs) following subcortical damage of the right hemisphere; their results suggest that the pulvinar is the principal site in the right human thalamus associated with spatial neglect, being involved in processes of space exploration and orientation of attention in space.

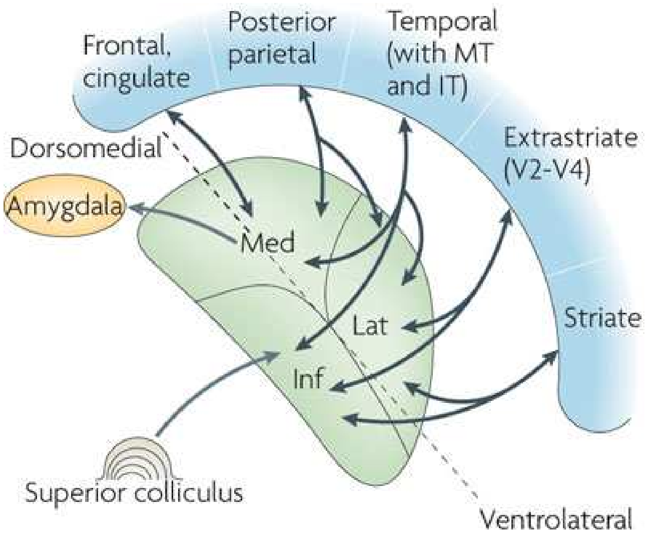


Fig.1.4 The pulvinar, the prominent medial part of the posterior end of the thalamus, works in a manner that integrates cortical-subcortical processing (picture taken from Nature Neuroscience).

1.4.4 The role of parietal cortex in attentional control

Parietal cortex is a crucial area for attentional control, contributing to spatial relations representation, as proved by lesional studies of patients with brain damage and brain imaging investigations.

Parietal cortex, situated at the intersection of visual, auditory, and tactile cortices, is considered an “association” cortex. It is highly connected to cortical and subcortical regions and is involved in transforming sensory input into motor output. While performing those activities, a host of cognitive computations are engaged including spatial representation and updating, attention, coordinate transformation, as well as abstract motor planning. In the picture below, anatomical regions of human parietal cortex are displayed.

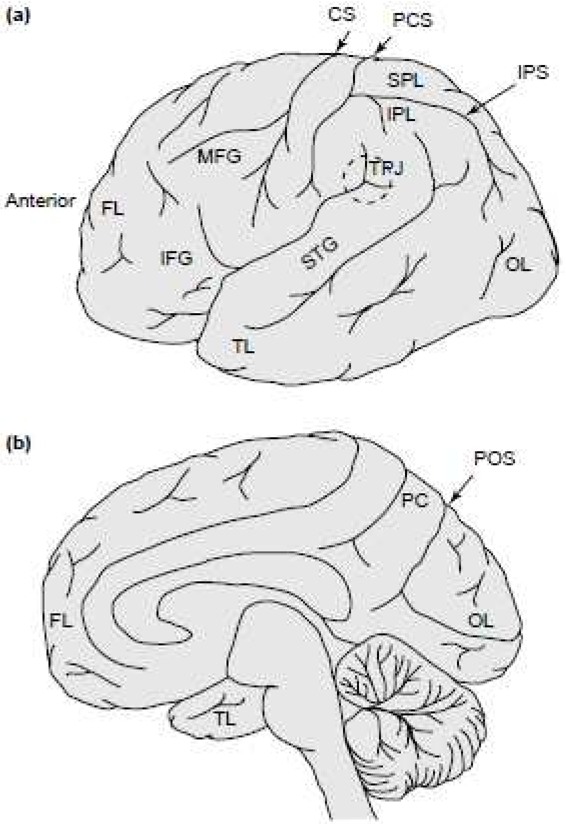


Fig.1.5. Schematic depiction of relevant anatomical landmarks projected onto the (a) lateral and (b) medial surface of the human brain. Parietal cortex is located posterior to the postcentral sulcus (PCS), which lies posterior to the central sulcus (CS), and superior to the occipital lobe (OL). It is divided by the intraparietal sulcus (IPS) into the superior parietal lobule (SPL) and the inferior parietal lobule (IPL). The continuation of the SPL on the medial side, anterior to the parietoccipital sulcul (POS) is called "cuneus".

A cognitive paradigm with a substantial impact on our understanding of how the parietal cortex controls visual attention is the covert orienting of visual attention task developed by Posner and colleagues (Posner, 1978, 1980; Posner, Snyder, & Davidson, 1980). As we already described in the previous paragraphs, in general, RTs are faster for validly cued targets when compared with RTs to invalidly cued targets. Faster RTs on valid trials result from the fact that attention has already been drawn to the location where the target subsequently appears. In contrast, for invalidly cued targets, the participant must first *disengage* attention from the cued location, and then *move*, and *engage* attention at the uncued location (Posner, Walker, Friedrich, & Rafal, 1984). This results in an increase of RT that is typically referred to as the "validity effect" or "cue-effect size (CES)".

The first systematic investigation of the role of the parietal cortex in covert attention was carried out by Posner and colleagues (1984). In this classic study, Posner and colleagues examined the influence of parietal lesions on covert visual attention in a group of 7 left and 6 right brain damaged patients with parietal lesions. The most important finding from this study was that parietal lesions disrupted the ability to disengage attention from ipsilesional stimuli. More specifically, patients were abnormally slow to respond to targets on invalidly cued trials when they were first cued to attend to the ipsilesional field, and the target subsequently appeared in the contralesional field. Interestingly, this “disengage deficit” was larger in patients with right than left parietal lesions, and was positively correlated with the amount of damage to the SPL, suggesting a critical SPL involvement.

The study about the role of parietal region in selective attention have been in part aimed at determining the anatomical locus within the parietal lobe that gives rise to the attentional biasing signal (i.e. the source) that ultimately initiates the sensory enhancement of the selected stimulus (i.e. the effect). In this field, the distinction between the automatic and voluntary attentional engagement have lead to the discovery of different sources for these two attentional mechanisms.

In particular, a number of functional magnetic resonance imaging (fMRI) studies have documented that bottom-up attentional capture, mediated by stimulus salience and/or relevance, is subserved by the temporoparietal junction (TPJ); when the source of the attentional signal is top-down or goal-directed, the superior parietal lobule (SPL) and the precuneus (PC) region are engaged.

Corbetta and Shulman (2002) recently put forward a model to explain the contribution of distinct regions of parietal cortex to the control of visual attention. They argue for two distinct but interacting attention systems within parietal cortex.

The ‘dorsal attention network’, which is bilaterally represented in the SPL/IPS is thought to be important for *allocating* attention to a specific region in space (i.e.. voluntary attention); the “ventral attention network”, which is lateralized to the right IPL/TPJ, is thought to be important for detecting salient events in the environment, by signaling the dorsal network to reorient attention towards meaningful stimuli or events.

Lesions to these two different networks result in very different clinical syndromes.

Specifically, lesions to the ventral attention network in the right IPL/TPJ commonly lead to spatial neglect, a disorder in which patients are unable to attend to stimuli in left hemispace. In contrast, lesions to the dorsal attention network in the SPL/IPS commonly lead to optic ataxia, a disorder characterized by misreaching to objects in peripheral vision (see for example Karnath & Perenin, 2005).

In the next paragraph the neuropsychological and anatomical correlates of spatial neglect will be described.

1.5 Spatial neglect

1.5.1 Neuroanatomical correlates and theories about spatial neglect

Patients with neglect are unable to attend to or acknowledge stimuli in left (neglected) space (Heilman, Watson, & Valenstein, 1993; Mesulam, 1999). In severe cases patients with neglect may only dress the right side of their body, groom the right side of their face, and eat food from only the right half of their plate (Robertson & Halligan, 1999). So, patients behave as if the left half of their world does not exist (Mesulam, 1981, 1999).

Damage to the IPL of the right hemisphere commonly leads to spatial neglect (Karnath, Ferber, & Himmelbach, 2001; Vallar & Perani, 1986).

However, even lesions of other cortical and subcortical regions of the right hemisphere can cause unilateral spatial neglect: frontal premotor regions (BA 44 and BA 6), superior temporal gyrus (BA 22), the subcortical grey nuclei (in particular thalamus and basal ganglia).

Finally, the spatial neglect can be associated with lesions of white matter tracts, especially the fronto-parietal connections and the internal capsule (Vallar, Perani, 1986).

Figure 1.6 shows the main regions and circuits whose injury can lead to spatial neglect.

In the case of patient with right hemispatial neglect (consequent to left sided brain lesions), no differences appear about the locations of lesions responsible for the deficits.

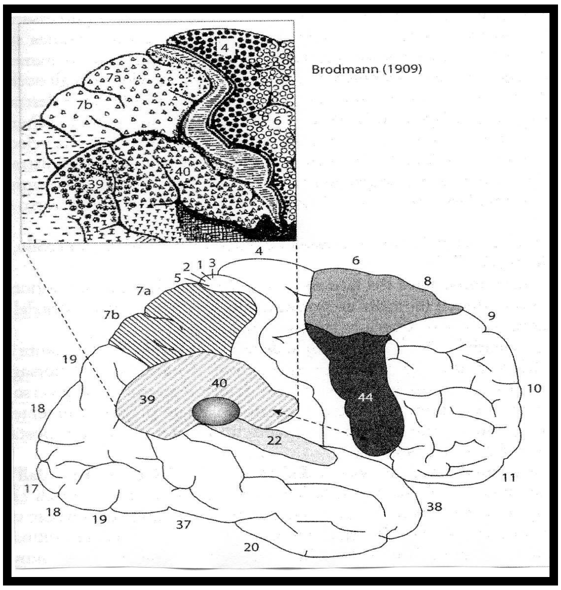


Fig. 1.6 Neuroanatomical areas involved in spatial neglect syndrome

Spatial neglect has traditionally been explained in terms of a disorder of attention: neglect patients show a strong rightward attentional bias, and/or with an inability to disengage attention from ipsilesional stimuli in order to reorient attention towards left, neglected space (for a review see Bartolomeo & Chokron, 2002). These deficits are thought to underlie the loss of awareness for left visual field stimuli in spatial neglect. This rightward attentional bias is supported by the observation of the behaviour of some patients with severe neglect, who do not only fail to attend to stimuli on the left side of space, but are seated with their head, body, and eyes deviated rightwards.

So, they seem magnetically attracted to stimuli on the right, since, even though they are capable of making leftward eye and head movements, they fail to explore the left half of space unless prompted to do so.

One of the earliest theories aimed at explaining the rightward attentional bias in neglect was the orientation bias model developed by Kinsbourne (Kinsbourne, 1987).

Kinsbourne proposed that each cerebral hemisphere orients attention to the contralateral side of space, with the left hemisphere orienting attention to right space and the right hemisphere orienting attention to left space. The two hemispheres are considered as mutually inhibitory; however, if the right hemisphere is damaged, as is the case of spatial neglect, then the left hemisphere becomes disinhibited and subsequently biases attention towards the ipsilesional (right) side of space.

This theory predicts that patients with neglect should not only fail to attend to items in contralesional (left) space, but should also display a “hyper-attention” to the right-sided items in ipsilesional (right) space, an hypothesis that remains controversial (see Fig. 1.7).

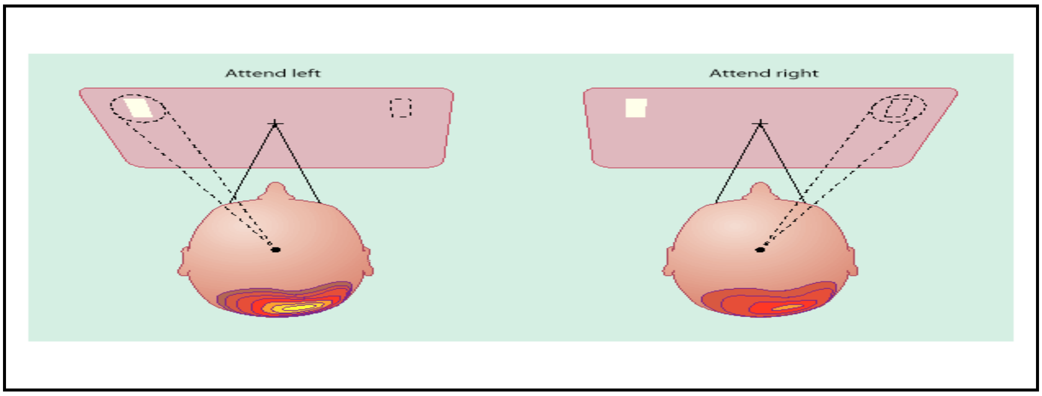


Fig. 1.7 The picture depicts the hyperorientation of attention shown by patients with unilateral spatial neglect toward the right hemi-field, namely the side ipsilateral to the cerebral lesion, by ignoring stimuli from the left hemi-field, i.e.. contralateral to cerebral lesion.

Although some studies have found evidence for hyper-attention to the right when comparing neglect patients to healthy controls (e.g. Ladavas, Petronio, & Umiltà, 1990), other researchs have found an overall slowing of RTs in both visual fields in patients with neglect relative to healthy controls, with RTs for stimuli in left space being slower overall in neglect patients (e.g. Bartolomeo & Chokron, 1999b).

In contrast, other theories of neglect have suggested that the left hemisphere directs attention to right space, whereas the right hemisphere directs attention to both left and right space (Heilman & Valenstein, 1979; Mesulam, 1981, 1999). The fact that neglect is much more common following right hemisphere lesions can be easily explained by virtue of the right hemisphere dominance for attention. That is, patients with right brain damage would be unable to attend to left space, while the undamaged left hemisphere would bias attention towards right space. However, if the left hemisphere was damaged, the undamaged right hemisphere would still be able to direct attention to both hemi-spaces, thereby decreasing the probability that the patient will demonstrate neglect for right space. Since the right parietal lobe is thought to control attention in both left and right space, this theory predicts that patients with neglect should also demonstrate deficits, even if less severe, for attention within ipsilesional (right) space. Consistent with this theory, Bartolomeo and colleagues demonstrated that patients with neglect have an overall increase in RT for both visual fields with RTs in the left visual field being slowest overall. Importantly, this overall increase in RT was larger in patients with more severe neglect. This is inconsistent with Kinsbourne’s orientation bias model (1987, 1993) which would predict that RTs for right visual field stimuli should *decrease* with increasing neglect severity. This suggests that although patients with neglect are *biased* to attend to items in right space, their ability to attend to this information is impaired, not enhanced (Bartolomeo & Chokron, 1999b).

A well known phenomenon, which regards neurologically intact subjects, is named “pseudoneglect”, i.e.. a leftward bias smaller than the rightward bias usually observed in USN patients. It can be present both with regard to representational and perceptual space (Bowers & Heilman, 1980; McGeorge et al., 2007; Jewell G. and McCourt M.E., 2000).

1.5.2 Clinical manifestations of spatial neglect

The spatial neglect is often associated with some deficits in the perception of contralesional stimuli and the monitoring of sensory and motor functions (Vallar, 2007).

The observed deficits are the following:

- Extinction: when two stimuli, right and left sided (competing stimuli), are simultaneously presented, patients declare to perceive only the one which is placed in the ipsilateral side, while being able to identify both stimuli when they are presented individually. Extinction may involve different modalities, visual, tactile and acoustic (Bisiach, 1991; Driver & Vuilleumier, 2001).

- Allochiria (or spatial transposition): the patient seems to correctly perceive the stimulus presented in the controlateral visual field, but he/she places it in the ipsilesional side (Grossi & Trojano, 2004; 2007; Halligan, 1992).

- Anosognosia: the patient does not recognize his/her illness, without signs of psychological distress for his/her condition (Prigatano et al, 1991; Vuilleumier, 2004; Cutting, 1978).

The hemi-inattention is often associated with left hemiparesis/hemiplegia, hemianopia and hemianestesia. Other not frequent manifestations associated with USN can be: anosodiaforia (lack of interest toward the hemiplegic limb); misoplegia (aggression toward the hemiplegic limb); somatoparaphrenia (delusions referred to hemiplegic limb).

When making a diagnosis of spatial neglect, the part of the space involved in the disease should be specified. In fact, there are three types of USN, in relation to the presence of an impairment regarrding mainly the personal, peripersonal and extrapersonal space; these three forms can occur together, or they can be dissociated in some patients (Berti & Smania, 2001; Bisiach et al., 1986).

The neglect of personal space affects the awareness of controlesional hemi-body. Patients with this disorder forget to dress, wash and comb in the controlesional side.

The neglect of the peripersonal space regards the space around the body, bounded by reaching movements. People with this kind of spatial neglect show deficits, for example, in taking items placed before them and delivering them to the examiner, but did not show difficulties when they perform tasks with stimuli placed at greater distances, ie beyond the range of their arm. The neglect of extrapersonal space concers what lies beyond the range of the arm.

There are also patients showing an impairment in their visual imagery (representational neglect): they may show deficitary description of mental images, in a similar way to what happens in the elaboration of visually presented stimuli (Bisiach, 1993; Bisiach & Luzzatti, 1978).

A deficitary exploration of extra-body space can be sometimes due to an impairment different from that regarding the perceptual exploration of the controlesional space; this is the case of the pre-motor neglect, involving the difficulty to start a movement toward the controlesional side with the ipsilesional arm. Pre-motor neglect can be assessed by using a variation of the line bisection task, in which the patient is asked not to manually bisect, but to point out the short end of segments already bisectioned: the patient systematically indicating the left side as the shortest is probably suffering from a perceptual deficit, while those who systematically indicate the right side probably suffer from a premotor deficit (Fischer, 2001).

Another distinction in the spatial neglect syndrome regards the presence of two main spatial frames of reference, which can be equally affected in patients: the ego-centric frame of reference (centered on the subject) and the allo-centric frame of reference (centered on the object). For example, if asked to copy a drawing with two daisies, in the first case, a patient will omit the flower placed in the controlesional side, while in the second case the patient will copy both flowers, sistematically failing petals on the left side of each daisy.

1.5.3 Evaluation and Rehabilitation of spatial neglect

The assessment of the presence of USN can be done through various tests, in which asymmetries in performance with respect to the left and right hemispace are measured and evaluated.

Three common tasks that are used to assess neglect are line bisection, in which the patient is asked to mark the center of a horizontal line placed at their body midline (Schenkenberg et al., 1980), cancellation tests (for example, Albert, 1973), in which the patient has to place a mark through target objects presented on a sheet of paper, and figure copying tasks in which the patient must reproduce line drawings (Marshall & Halligan, 1999). In particular, line bisection tasks have also been employed in the study of pseudoneglect with healthy subjects, showing that neurologically normal subjects systematically misbisect space during visual line-bisection or similar tasks, generally dislocating the centre to the left when bisecting horizontal lines (see for a review Jewell & McCourt, 2000).

Besides, patients may be asked to read some sentences, in order to highlight the presence of neglect dyslexia, with patients omitting the initial part of a phrase or first letters of each word.

Tasks of drawing from memory provide a mean to assess the presence of representational neglect. In fact, since the spontaneous drawing is based on the activation of mental representation of objects, asking a patient to draw a symmetrical object can show if he/she tends to omit or distort the left side of it. By this way, allochiria can also be observed, with some patients putting, in the drawing of a clock, the numbers between 6 and 12 on the right side of the clock.

Another task developed in order to assess representational neglect requires patients to provide a verbal description of a famous square (as the Milan Duomo) from two opposite perspectives (Bisiach & Luzzatti, 1978).

However, patients in chronic stages of the disease sometimes do not obtain pathological performances on such tasks, even if they still present spatial neglect symptoms in everyday activities. For these reasons, more ecological tasks have been developed.

The Behavioural Inattention test (BIT, Wilson et al., 1987) is a battery of six conventional (paper and pencil) tests and nine trials involving behavioural tasks, similar to everyday situations (eg., dialing a number on a phone, reading and setting a watch and using a maps). Besides, another scale involves only ecological tasks (Zoccolotti et al., 1992) and is composed by two parts: in the former, patient behaviour is evaluated during the execution of four activities (serving tea, distributing card for playing a game, describing two figures in black and white, a picture and an environment). In the second part, personal neglect is assessed by means of tasks such as shaving for men, to get the powder for women, combining hair and to put on glasses are administered.

The first attempts to rehabilitate patients with unilateral spatial neglect dating back to the early 60s of last century.

Actually, the rehabilitative procedures for USN can be divided into two main types:

- Behavioral methods, aimed at encouraging the patients to explore the contralesional space through explicit verbal suggestions or calling their attention, using a light or a sound that is presented to the left side; these methods usually require the active partecipation of patients, who are asked to orient their attention toward contralesional stimuli, with the aid of cues able to attract attention (such as a red vertical line) toward the neglected side (Pizzamiglio, 1992).
- Physiological methods, which involve the administration of sensory stimulation, the recruitement of motor activity, asymmetric along the left-right dimensions (Robertson et al., 1993), or which modify the activity of the cerebral hemispheres, for example with TMS (see for example Fierro et al., 2006). Other examples of

these methods are represented by the TENS (transcutaneous electrical nerve stimulation) (Guariglia et al., 2000; Vallar et al., 1996) and the use of adaptation to prism lenses (see for example Rode, 2006).

The main objective of both methods is addressed to the attentional component and in particular the reduction of the pathological ipsilateral orientation, improving management skills and the reintegration, even if only in part, of the damaged representation of the controlesional space.

1.5.4. Conscious and unconscious detection of controlateral stimuli in hemispatial neglect

One problem currently much debated is about the critical role of stimuli presented in the neglected space, that is, those stimuli to which the patient denies the existence. In that regard, two assumptions were made and both require that a stimulus, in order to reach the level of consciousness, must be selected by the mechanism of selective attention.

The two theories are the early selection hypothesis and the late selection hypothesis (see paragraph 1.2).

The responses to stimuli in controlesional side may not be guided by attentional processes, and this is demonstrated by the fact that many of them deny that even a stimulus is presented in this field.

A study by Berti and Rizzolatti (1992) has shown that the stimulus on which the patient can not direct the attention, and therefore ignored, is processed at least to the level of category.

These results were confirmed by a study of Làvadas, Paladini and Cubelli (1993) in which it was shown that the neglected stimulus is processed to the level of the attribution of meaning, thus confirming the hypothesis of a late selection.

A surprising dissociation between conscious processing and unconscious processing in patients with hemi-inattention was also highlighted in a series of experiments in which patients with USN, when placed in a position to provide answers that do not require explicit information processing in the neglected part of space, were able to process the neglected stimulus, to extract the meaning. Marshall and Halligan (1988) used pairs of stimuli depicting two houses positioned vertically one above the other. In each pair there were two houses, a house without a fire with flames and the other on the right or left. The patient never counsciously noticed the fire on the left, but, with a forced choice, he/she chose nine times out of eleven the house without burning by stating that it was bigger.

Bisiach and Rusconi confirmed, in part, these results in a larger sample of patients and different stimuli (1990).

Similar striking dissociations between conscious and unconscious processing have been reported in other experimental paradigms leading to the same result also with regard to reading (Làdavas, Paladini & Cubelli, 1993).

One possible interpretation of the observation of an implicit elaboration in neglect is that the encoding of the space is a necessary precondition to be fully aware of stimuli presented in that space (Berti, Rizzolatti 1992; Làvadas, Berti 2000). It would therefore be necessary, to achieve full awareness of a stimulus, the simultaneous and in parallel activation of two representations: the representation of space (related to the activation of occipito-parietal stream or “where” system) and the representation of the object (related to the activation of the occipitotemporal stream, or “what” system).

If the representation of space is compromised, as in the case of neglect patients, the activation of one representation may not be sufficient to represent the object in a conscious way, but it may be sufficient for a processing which does not reach the threshold of consciousness.

The consequence of this mechanism is that the patient remains unaware of the stimulus presented to him, even if it can be demonstrated by indirect evidence that the stimulus is still processed.

CHAPTER 2

EMOTIONS: NEUROANATOMICAL BASIS AND MECHANISMS

2.1 Definition of emotions

Although it is unlikely to find a single definition of emotion, it can be generally defined as a subjective reaction to a saliente event, characterized by physiological, behavioral and experiential modifications (Sroufe, 1996). In addition to this initial label, we are faced with large differences in both the definition of these components, and the weight that each has on the production of emotion. If we want to find a unifying element we have to rely to a very general view, namely that emotions are considered by all the researchers the basic motor of human behavior and that each of the basic emotion has their own specific adaptive functions (Izard, 1991).

Researchers today agree that the emotion does not represent a negative and disorganizing experience, with only a biological basis, as previously believed; rather, it is a complex and multidimensional experience, with a strong function of cognitive-affective organization, mediating the relationship between the body and the environment.

In a more general sense the emotion can be understood as a deviation from the normal state of rest of the body, accompanied by an impulse to action and some specific internal physiological reactions, each of which is expressed in a different manner.

The definition adopted by Sroufe has the advantage of emphasizing the fact that every emotional episode consists of several components:

a. The triggering event is always specific to each emotion. The surprise, for example, is evoked by an unexpected event, the fear by a threatening situation, shame hurts their self-esteem and so on.

b. The physiological components, such as rapid heartbeat, labored breathing, abundant sweating, skin conductivity and other functions controlled by the autonomic nervous system.

c. The experiential components, namely the feelings that the situations arouse in everyone: this is the aspect that we are more familiar with, due to personal experience.

d. Behavioural change, i.e. the overt aspect of which people who observe the emotional state of another individual are aware.

The most overt signs are facial expressions, which have been a topic of great interest for research on emotions espression and recognition; changes in voice and gestures are the signals that allow other people to understand not only the individual is emotionally activated, but also to identify the specific emotion (Shaffer, 2005).

The list of emotions is variable, but we can make a distinction between primary emotions, that are anger, fear, surprise, sadness, disgust and happiness, and secondary or complex emotions, which include compassion, embarassement, shame, guilt, pride, envy, gratitude, indignation and contempt (Benussi, Nichelle, 2007).

2.2. The main Theories about emotions

In the last century, many theories about the origin and expression of emotional experience have been proposed.

In 1884, William James and Carl Lange proposed a theory of emotion, stating that we experience a certain emotion in response to physiological modification in our body.

This conceptualization, defined as the peripheral theory of emotion, assumes the presence of a retroactive mechanism, linking the physiologycal activation or arousal to the interpretation of the variations from the rest state into the central nervous system.

Cannon and Bard, in opposition to the peripheral theory, proposed a central theory (1928-1929) according to which the center responsible for emotions is localized into the hypothalamus. The cortex is not involved in emotional responses, but in conscious experience of emotion; besides, visceral responses are not used to differentiate the emotions or to give rise to awareness, but are used to provide the energy supply needed to implement the emotional responses.

These views of James-Lange and Cannon-Bard represent different perspectives, although both related in some way to an instinctual aspect of emotions, and both partial, since they assigned unilateral correlates to emotional experience, with particular reference to its neurophysiological aspects.

Alongside these historical theories, we find the cognitive-activational theory of Schachter and Singer (Schachter and Singer, 1962), which has effectively contributed to introduce a genuine psychological dimension in the study of emotions.

The emotion is defined as the result of two components: the physiological activation (arousal) and cognitive processes that are the necessary conditions for the occurrence of an emotional state. However, their mere presence is not sufficient to generate an emotion, since an attribution that establisches the causal connection between the cognitive act itself and the arousal is needed. The interpretation of the physical and social context is a crucial element in the generation of an emotional experience.

Starting from the bifactorial conception of Schachter and Singer, the debate between emotion and cognition started and the so-called Appraisal theories were developed (Schachter, 1962). These have established themselves in the 80', and according to them the emotions are related to the way in which individuals give meaning to the stimuli of their physical and social environment.

Therefore, as highlighted by Frijda (Frijda, 1988), emotions arise in response to the structure of meaning in a specific situation.

A recent and noteworthy contribution to the theory of emotions is given by Damasio, who proposed an holistic conceptualization, overcoming the dichotomy between mental and bodily aspects of emotional experience (the so-called "Cartesian Error").

Damasio stated that mind and body should be regarded as integrated and interdependent components of a single organism, able to intelligently and effectively interact with the environment; for the Author, the emotion is the combination of the mental evaluation process of a certain situation and somatic changes.

Continuing the thought of James, Damasio believes that the body represents a kind of resonant surface to the emotional situations. The mind works in synergy with the body to evaluate the various internal and external stimuli. In this perspective is not only the mind to lead the body, but also the body to guide the mind, because its positive or negative, present or stored, resonance is a primary evaluation system of stimuli, giving them different weights and meanings (Gal, 2002).

In the next paragraph, the psycho-evolutionary theory of emotions will be described; a larger part has been dedicated to this theory, since it is particulary coherent with the object of this work and an important tool for the evaluation of facial expression recognition (The Facial Coding Action System) has been developed starting from Ekman's study.

2.2.1 The psycho-evolutionary theory of emotions

Tomkins and Pluchick, referring directly to the theory of Charles Darwin (Darwin, 1872), believe that emotions are closely associated with the realization of universal purposes, related to the survival of species and individuals, such as the escape for the protection of self in relation to fear.

This position, developed by Ekman (Ekman, 1972) and Izard (Izard, 1978), involves the acceptance of the thesis about the innate facial expressions of emotions (Anolli, 2002). Psychoevolutionistic theories presuppose a categorical conception of the emotions, believed as distinct and separate categories. Emotions are so distinct unites, regulated by specific programs of neural activation and expression.

Darwin, in his classic work, “The Expression of the Emotions in Man and Animals” (1872) held that our emotional experiences resides on a innate and universal basis. Darwin made two interesting hypothesis, arguing that humans possess an innate and universal repertoire of distinct facial expressions, and that those expressions are assigned with the correspondent meanings through an innate mechanism of recognition. As already mentioned, not full agreement is present among researchers on what the primary or basic emotions in humans are, even though most of them are quite unanimous in recognizing those who, according to the categorical conception of Paul Ekman (Ekman, 1984), are the six main emotional dimensions: anger, disgust, happiness, surprise, fear and sadness. The Author also stated that the characteristichs of basic emotions were the following: distinct universal antecedent, universal expressions, different physiological correlates, consistency between the emotional responses, rapid onset, short duration, automatic evaluation, spontanous activation and continuity between the human and animal expressive behavior (Ekman, 1992).

Other researchers, such as Plutchik (Plutchik, 1980) and Frijda (Frijda, 1986), do not rely only on facial expressions, but propose the universality of more global actions involving many parts of the body.

Secondary emotions, such as anger, shame, guilt, pride and envy, would not be easily identifiable as the primary ones (Izard, 1991; D'Urso, Trentin, 1998).

According to Plutchik complex secondary emotions were a mixture of emotions; they are also called "complex" because they require a self-assessment in a specific context. Izard (Izard, 1977, 1991), a very representative Author from this current, proposed the theory of differential or discrete emotions, according to which organisms have a repertoire of pre-programmed basic emotions with high adaptive value and functional for survival of individual or species.

Izard theory states that: basic emotions are the primary motivational system; each basic emotion has phenomenological distinct aspects; basic emotion such as joy, sadness, and anger give rise to different behaviours and internal experiences; the basic emotions interact with each other, activating, amplifying and attenuating each other; the emotional process interact and influence the homeostatis, the cognitive and motor processes (D'Urso, Trentin, 1998).

2.3. Emotion and Brain: neurophysiologycal basis of emotion

The brain activates and regulates the physiological aspects of emotion. Currently, all seem to agree, albeit with small differences, identifying the limbic system and frontal lobes as the neurological substrate of emotions.

The prefrontal cortex performs tasks of behavior organization and anticipation. One of the most important human qualities, which depends on the frontal lobes, is the ability to regulate emotions.

Amygdala and hypothalamus have an essential role in the emotional process. The hypothalamus is the area of the brain that coordinates and regulates the CNS through the complex hormonal activity, regulating different functions within the organism, such as the balance of body temperature.

The amygdala, defined by neuroscientist Joseph LeDoux (LeDoux 1992, 1993) as a sort of "computer of emotionality", records and triggers fast and instinctive emotional reactions. The amygdala acts as a store of emotional memory and is the repository of the very meaning of events; this structure provides an assessment of particular external stimuli, and many studies have shown that damage to the amygdala or its disconnection from other cerebral areas produces serious disturbances in the evaluation of pleasant or threatening stimuli (D’Urso, Trentin, 1998).

The endocrine system comes as part of the emotional function of mediation and integration of the interaction between autonomous nervous system (ANS) and central nervous system (CNS). The CNS control is exercised through the connections between hypothalamus, pituitary and other glands like the thyroid and the gonads. (D'Urso, Trentin, 1998).

In the next paragraphs the main component of the emotional system, i.e. the limbic system, the amygdala and the frontal cortex, will be described.

2.3.1 The limbic lobe of Broca

In a study published in 1878 by the French neurologist Paul Broca, it was described that on the medial surface of the brain of all mammals there is a group of cortical area, distinct from the sorrounding cortex; Broca called this set of cortical areas “limbic lobe”, because they formed a ring around the brain stem (Fig. 2.1).

The limbic lobe is made from the cortex around the corpus callosum, particularly the cingulate gyrus, and the cortex on the surface of the medial temporal lobe, including the hippocampus. However, Broca did not write anything about the importance of these structures for the emotions, and they were long believed to be involved in olfactory perception (Bear, Connors, Paradiso 2002).

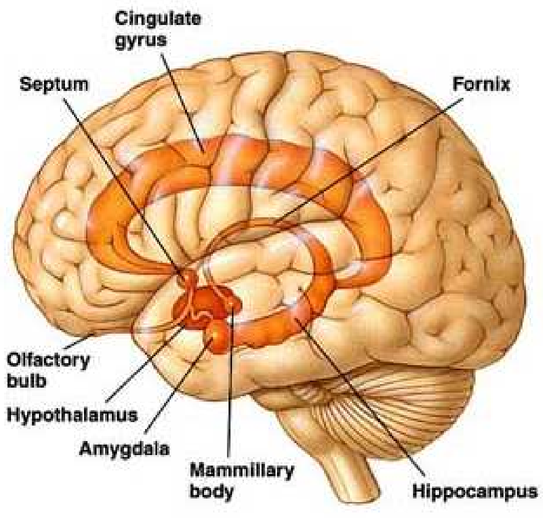


Fig. 2.1 The limbic system, composed by primitive areas, including the cingulate cortex, the parahippocampal cortex and the hippocampus.

According to Papez, the function of the limbic lobe was probably more interesting than what was assumed. His argument was based largely on the neuroanatomy. Papez himself knew that the hypothalamus influences the expression of emotions; he also knew that higher cognitive functions influence emotional behavior. Papez showed that between the cerebral cortex and hypothalamus there are reciprocal connections formed by circuits that were referred to by Papez circuit. (Umiltà, 1999).

2.3.2 The Papez circuit

Papez suggested that the cortex was involved in the experience of emotions. In fact, in the presence of damage to certain areas of the cortex, serious disturbances of emotional behavior were sometimes observed. In addition, tumors located close to the cingulate cortex are associated with emotional disorders including fear, irritability and depression.

In the circuit of Papez (Fig. 2.2), the hypothalamus control the behavioral expression of emotions. The hypothalamus and neocortex are arranged so that they can influence each other, and create a link between their emotional expression and experience.

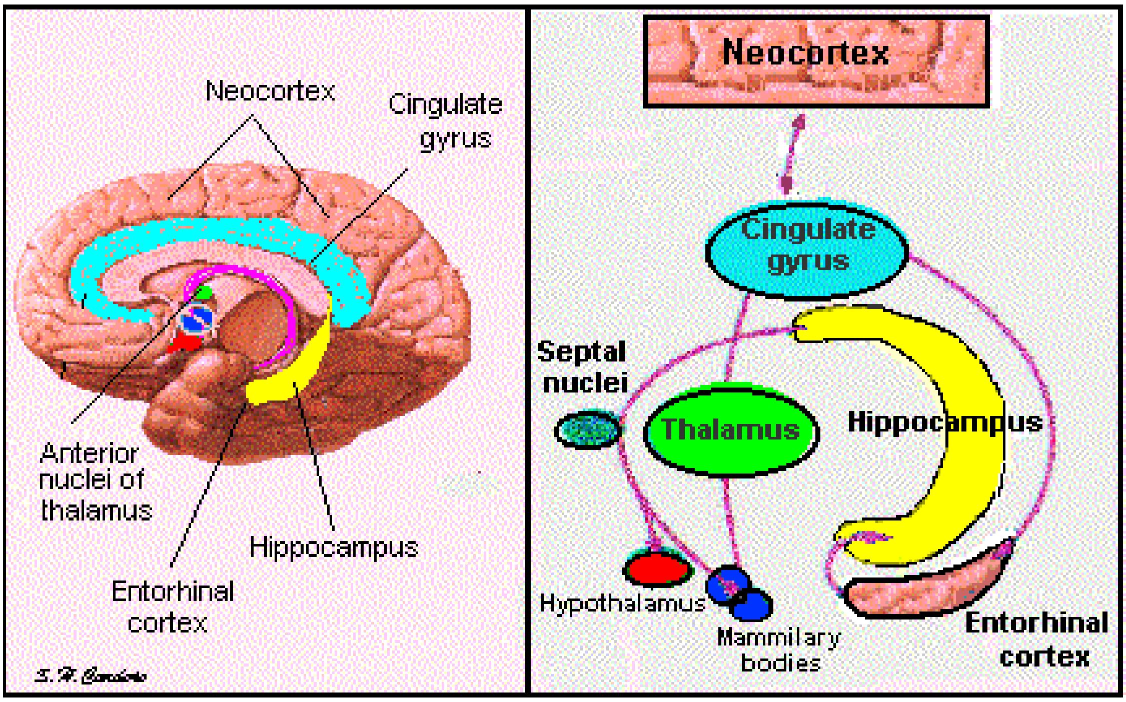


Fig. 2.2 The Papez circuit, where hippocampus plays a crucial role since connects cortical area to hipotalamus.

In this circuit the hypothalamus (especially the mammillary bodies) sends projections to the nucleus of the anterior dorsal thalamus, which in turn projects to the cortex of the cingulate gyrus. The latter, along with many other areas of the cerebral cortex, sends projections to the hippocampus. Finally, the hippocampus, via the fornix (a thick bundle of nerve fibers), project back to the hypothalamus.

Papez hypothesized that these pathways were necessary connections so that the cortex exerts a regulatory function on the expression of emotions.

But some critics were moved to the theory of limbic system; in particular, some areas traditionally included in the limbic system, such as the the hippocampus, the mammillar bodies and the anterior thalamus, play a more relevant role in cognition than in emotional behaviour.

Over time, some new elements were added to this circuit, so that it was named “the limbic system”.

One of the most important new component of the limbic system is the amygdala, a mass of nuclei hidden in the white matter of the temporal lobe, in rostral position in relation to the hippocampus (Umiltà, 1999). Nowadays it is known that the amygdala, which Papez had not mentioned, plays a very important role in regulating emotional behavior.

2.3.3 The amygdala

The term “amygdaloide nucleus” was used for the first time by an anatomist Karl Friederich Burdach, to identify an almond shaped cell mass of grey matter located in the medial temporal lobe (Sergie, Armony 2006) (Fig. 2.3).

The amygdala is divided into three parts: the basolateral nuclear group, the corticomedial nuclei and the central nucleus, each of these parts having their own set of connections with other parts of the brain. The group of cortico-medial nuclei has extensive connections with the olfactory bulb and the olfactory cortex. The group of nuclei of the basolateral region, which is particularly voluminous in humans, has its main connections with the cerebral cortex, especially the sensory association areas. The group of nuclei of the central region is characterized by connections with the brainstem, the hypothalamus and visceral sensory areas such as the nucleus of the solitary fascicle.

Two important pathways carry information within the amygdala and outside of it: the ventral amygdalofugal pathway, an aggregate spread of nerve fibers, and the stria terminalis, a more compact fiber bundle.

The amygdala connects the cortical regions that process sensory information with effector systems of the hypothalamus and brainsteam.

Cortical afferents provide information about visual, somatosensory and acoustic stimuli, which have already been subjected to a high degree of elaboration. It has been shown that the amygdala is also innervated by fibers coming from the insula, a cortical area that processes the visceral stimuli.

These cortical afferents distinguish the amygdala from the hippocampus, which receives only sensory stimuli that have not yet been processed.

The amygdala also receives sensory afferents directly from some thalamic nuclei, the olfactory bulb and the nucleus of the brain stem solitary fascicle.

Physiological studies have confirmed the existence of this convergence of sensory information on the amygdala. As a result many of the amygdala neurons respond to visual, auditory, somatosensory, gustatory and olfactory stimuli.

To induce a response are also often required significantly complex stimuli (for example, faces). The projections that reach the hypothalamus and the brainstem from the amygdala (and maybe even go up to the spinal cord) allow the amygdala to influence the activity of both the visceral nervous system and the somatic motor system (Price, Russchen & Amaral 1987).

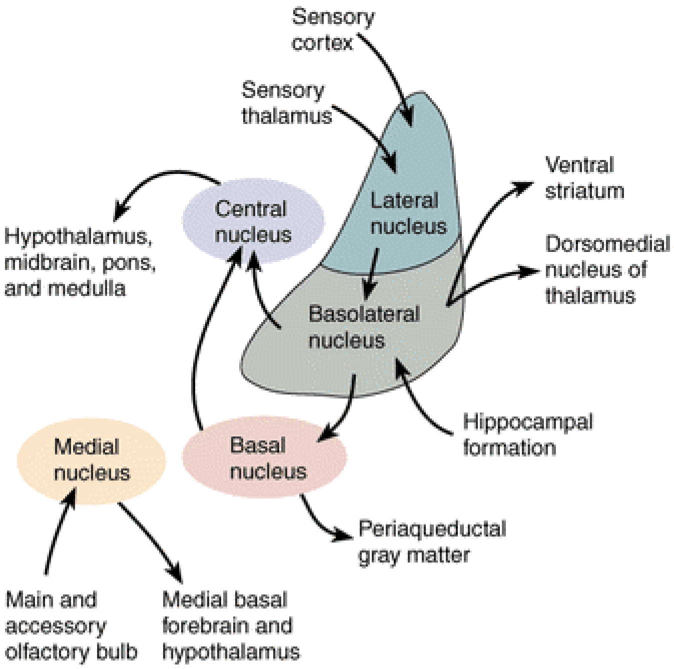


Fig. 2.3 Diagram of the major divisions and connections of the Amygdala

2.3.4 The frontal lobes and the emotions

The prefrontal cortex is divided into dorsolateral and ventromedial portions. These two regions, which are mutually interconnected, can modulate the selection of emotional information through different mechanisms. Dorsolateral areas have reciprocal connections with cortical sensory and association areas, but not directly with the amygdala, and appear to be involved in maintaining the selected cortical representations in working memory. Ventromedial areas, including the orbital cortex and the cingulate cortex, in contrast, have reciprocal connections with the amygdala and, therefore, may modulate the amygdala elaborations as well as be influenced by the amygdala itself. These anatomical connections allow the frontal lobes to select the emotional information in a flexible way, in agreement with the current goals and task demands. In summary, while the dorsolateral regions work in order to keep the relevant representations in working memory, regardless of whether they are emotional in nature or not, the ventromedial regions are positioned so as to play an important role in processing emotionally salient information. Thus, the ventromedial areas are associated with the direction of attention towards significant stimuli. In particular, the anterior cingulate gyrus is involved when participants have to choose between competitive performances differing in their emotional value.

The prefrontal regions are not only able to select the emotionally relevant input, but may also be involved in the contrary, i.e. in their suppression. Indeed, several studies have shown that the activity of the amygdala can be modulated by emotion regulation strategies controlled by the frontal lobe.

In the ventromedial region, an important role is played by the orbital frontal cortex, which is the portion of the prefrontal cortex which occupies the ventral surface of the frontal lobe. Like the amygdala, it receives highly-processed information from all sensory modalities and, based on the pattern of its connectivity, it has been divided into medial and lateral networks. The medial network of the orbital frontal cortex has strong connections with the hippocampus and associated areas of the cingulate, retrosplenial, and entorhinal cortices. The lateral network has been further subdivided into a caudal sector, that is mainly interconnected with the amygdala, midline thalamus, and temporal pole, and a rostral sector, that has more consistent connections with the insula, mediodorsal nucleus of the thalamus, inferior parietal lobule and dorsolateral prefrontal cortex.

Thus, the orbital frontal area receives information about all aspects of the external and internal environment, from thalamic nuclei involved in associative aspects of memory, and from the amygdala and temporal pole that are thought to regulate emotional states. The connections between the orbital frontal cortex and the amygdala allow the modulation and self-regulation of emotional behavior in relation to rapid changes in a social situation. Moreover, the orbital frontal cortex sends inputs to brain regions, such as the preoptic region of the lateral hypothalamus, that are critical for hormonal modulation of emotions, and to motor centers, such as the head of the caudate and the ventral tegmental area, that are critical for motor control of emotional behaviors (Selemon and Goldman-Rakic, 1985).

In conclusion, the anatomical organization and the reciprocal connections between the orbitofrontal cortex and the amygdala suggest that these brain regions may co-operate within a system relevant for the maintenance of intra-specific social bonding and the self-regulation of emotional states. Converging evidences from rodents, humans, and non-human primates indicate that the interconnections between the basolateral complex of the amygdala and the orbital frontal cortex are crucial to the formation and use of expectancies in the guidance of goal-directed behavior (Gottfried et al., 2003; Holland and Gallagher, 2004).

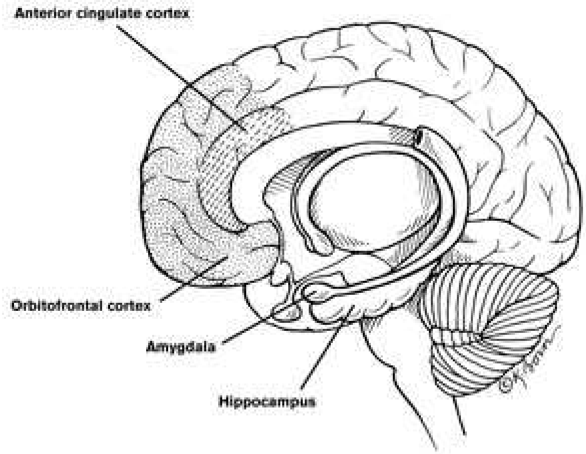


Fig.2.4 A picture of the circuit, including the orbitofrontal cortex, involved in the decision making process. The orbitofrontal cortex helps us weigh immediate payoff against later rewards. The amygdala marks what is emotionally important. The anterior cingulate responds when we make mistakes. The hippocampus coordinates memories of past events. (Image by Kathryn Born).

2.4 The evaluation of the emotional significance of an event

At the beginning of last century neurophysiological research had highlighted the importance of subcortical structures in the evaluation process of an emotional event and of cortical structures in the control and processing of emotional responses. Experiments performed on decorticated animals had shown responses of anger at all comparable to those provoked by emotional stimuli themselves (Goltz, 1982). Similar results were described by observing patients with lesions of the diencephalic-cortical pathways, the behavior of these patients being characterized by the onset of sudden and unexplained crying and laughter.

The reactions of anger evident in decorticated animals and the behavior of these patients may be explained by attributing a function to cortical structures of control of emotional processes underlying subcortical structures.

These experimental and clinical observations led Papez (1937) to suggest that the hypothalamus, the anterior nuclei of the thalamus, the cingulate gyrus, hippocampus and their connections constitute a harmonious mechanism which would arouse the emotions internally and at the same time helps to organize emotional responses. The hypothalamic component of this system would be more than others involved in the attribution of emotional significance to sensory stimuli and emotional expression, while the cortical component is responsible for emotional experience.

In the same year in which Papez proposed the existence of an emotional circuits in the brain, the neuroscientists Ahaeinrich Klüver and Paul Bucy at the University of Chicago found that the bilateral removal of temporal lobes performed on rhesus monkeys had dramatic effects in the responses of animals to situations of fear; surgery intervention produced a number of behavioral abnormalities that lead to blindness, mental and emotional changes, and this constellation of symptoms has been called Klüver-Bucy syndrome. The emotional changes in monkeys suffering from this syndrome mainly consisted in the reduction of fear. The primary emotion most studied is fear, and several studies have shown that the amygdala plays an important role in its preparation. The amygdala is also involved in many aspects of emotion and its injury in humans is associated with reduced emotional response.

All the symptoms of Klüver-Bucy syndrome produced by the monkeys were also seen in humans with temporal lobe damage that extended to the amygdala; in addition to the problems of visual recognition, oral behaviour and ipersexuality, people have flattened emotions.

Downer in 1961 made an important experiment that revealed the predominant role of the amygdala in the evaluation of emotional stimuli; he cut the callosal commissures and optic chiasm in a monkey thus preventing the interemispheric transmission of the stimulus, and performed unilateral ablation of amygdala; in this way he noted that by sending visual stimuli with emotional content to the ipsilateral eye, the animal showed an attitude of indifference to the stimulus, and conversely the same visual information sent to the contralateral eye produced in animals emotional reactions fully compatible with the stimulus. These results were later confirmed by several authors, showing that the recognition of the positive and negative valence of visual information takes place only after the information is processed by the amygdala.

LeDoux in 1996 was the first to show how amygdala lesions prevent the ability to learn and express a conditioned response to a neutral stimulus associated with an aversive unconditioned stimulus; Phelps and LeDoux (2005) applied the paradigm of fear conditioning to a woman, who reported bilateral lesions of the amygdala: in this experiment a blue square was shown, which was associated with a slight electric shock to the wrist; the woman was aware that the presentation of the square was associated with electric shock, but was unable to develop an appropriate psychogalvanic response thus demonstrating that she had not acquired a conditioned response.

The amygdala also seems to be involved in social responses even though this is more evident in animals other than man, eg the monkeys who are injured in the amygdala have considerable difficulty in meeting the social hierarchy and demonstrate forms of aggression, thus causing to be expelled from the group.

Amygdala lesions in humans causes a selective deficit in recognizing facial expressions of fear; it is hard to find in humans aggressive behaviours and no respect of social norms as a result of an injury to the amygdala as occurs in primates; these behaviors are observed in humans following orbitofrontal lesions.

Recent findings help to discriminate between the role of amygdala and of orbitofrontal cortex in emotional processes. In particular, while the amygdala appears to be a neural system that acts to detect the significance of objects or events for the individual, the orbitofrontal cortex makes use of this information to guide goal-directed behaviors and to adjust behavior appropriately in accordance with changing conditions (Bechara et al., 1999; for review see Holland & Gallagher, 2004). Prefrontal lesions that include the orbital sector result in dramatic emotional changes in humans, including euphoria, irresponsibility, and lack of affect (for review see Damasio, 1994; Rolls, 1999). Patients with damage to the orbitofrontal region manifest impairment in real-life decision making, associated with changes in their autonomic responses (Bechara et al., 1994) and failed to monitor changes in the reward value of stimuli and to use this information to guide their behavior (Hornak et al., 1996).

LeDoux (1987) proposed a model of a two-way connection of the amygdala, which, on the one hand, receives projections from primary sensory areas and the secondary association areas (cortical pathway) and on the other hand receives sensory information from different thalamic nuclei (subcortical or thalamic pathway). These two routes, in addition to being anatomically different, have different functions in the analysis of emotional information. The thalamic pathway (short route) sends a very poor information on the characteristics of the stimulus, even if sufficient to start an undifferentiated emotional response, not necessarily compatible with the stimulus situation.

The information that reaches the amygdala via the cortex (long route) is much detailed, in relation to perceptual and semantic characteristics of the stimulus, and help the subject to prepare an adequate response to the situation.

The thalamic pathway is much faster than cortical and it was thought that, in addition to provide an initial emotional response, it serves the amygdala to prepare to receive more detailed and comprehensive information about stimulus nature by the cortical structures that have allowed the identification of perceptual and semantic attributes. The fact that the amygdala can process the emotional significance of a stimulus received from the thalamic pathway irrespective of cortical one explains the phenomenon of cortical processing of stimulus emotional value, in the absence of recognition of perceptual and semantic attributes; in every day life the two source of information operate in parallel, but there are situations in which one takes precedence over the other.

LeDoux says that through the thalamic pathway the information reach the amygdala, which performs an essential elaboration of the stimulus, processing only the emotional information; as a consequence, this process would not reach the awareness. In order to have awareness of its effect, it is also necessary that the information is analyzed from cortical structures and that it later reaches the amygdala via the cortex: only at this level it is possible to recognize the symbolic attributes of the stimulus, analyzing the physiological changes produced by the event and prepare an appropriate response to the situation. We can therefore say that our emotional behavior can be driven both by cortical and subcortical structures. The subcortical structures are equipped with innate neuromotor programs that can generate a specific set of automatic responses, especially for some of the basic emotions.

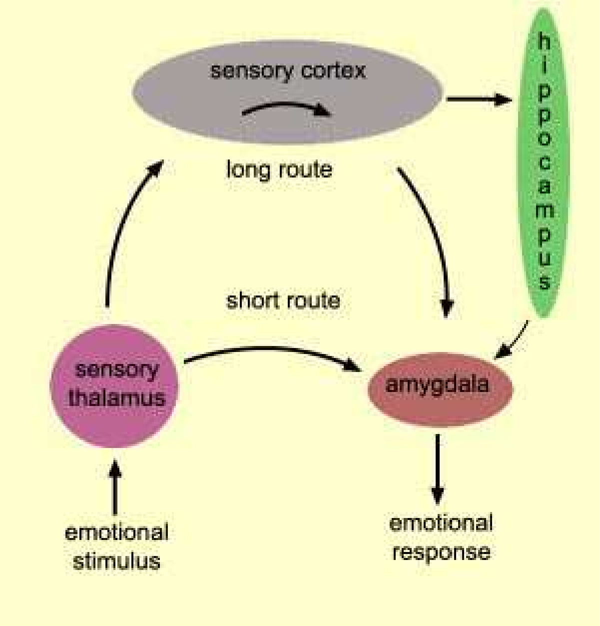


Fig. 2.5 LeDoux (1987) model of a two-way connection of the amygdala: the thalamic pathway (short route) and the cortical pathway (long route).

2.5 The evaluation of the emotional meaning of an expression

The comprehension of the emotional significance of facial expression is based on a set of skills, allowing an individual to detect some behavioral signs that provide information on the emotional state of his fellows. Both the facial expressions and the voice tone are non-verbal signs of an emotional state, which discrimination is essential for the communication of emotional experience (Berti, Ladavas, 1995).

The majority of brain structures involved in the recognition of basic emotions are involved in the drafting perceptual identification of the geometric configuration of facial features in order to discriminate between different stimuli on the basis of their characteristics. The recognition is based on several strategies, for example, the recognition of a fearful face can occur by linking the perceptual properties of the stimulus face to the knowledge of various processes which include the already known components of the concept of fear, the lexical label "fear" and the perception of the emotional response of fear (Adolphs, 2002). Several structures are involved in the recognition of facial expressions, among them the occipitotemporal cortex, the amygdala, the orbitofrontal cortex, basal ganglia and right parietal cortex can be considered.

These structures are involved in multiple processes and it is not easy to assign a specific function to each of them (Adolphs, 2002).

The recognition of faces and emotions are two independent processes, at both functional and anatomical level. Numerous studies have showed that prosopagnosics patients, or patients who are not able to recognize the face of a known person, nor to judge the familiarity of that face, are still able to recognize individual emotional expression (Bruce & Young, 1986).

A further demonstration of this phenomenon has emerged from the study of some patients with Urbach-Wieth disease, a rare autosomal recessive disease that is associated with a selective and complete bilateral amygdala damage; in these patients, a severe deficit in the recognition of certain emotional expressions such as fear is associated with a good ability to recognize the sex and identity of faces (Adolphs, Tranel, Damasio, 2003). The perceptual processing of faces is based on a set of visual cortical regions, but the fusiform gyrus is particularly involved in the representation of the static features of faces and thus contributes to the consolidation of identity, while the superior temporal gyrus is primarily involved in representation of the dynamic and changing faces, and contributes to the encoding of facial expression and gaze direction (Adolphs, 2002). The amygdala, as stated in the previous section, plays an important role in the recognition of emotional expressions, particularly in the recognition of fearful faces. A study by Ralph Adolphs University of Iowa on a thirty year old woman with bilateral amygdala damage showed deficits in selective recognition of fear expressed by the faces of people. Bilateral lesions of the amygdala, as well as impairing the recognition of fearful faces, would seem also to determine deficits in the recognition of other negative emotions such as anger, disgust and sadness even if these results are still under debate (Adolphs, 2002). Orbitofrontal cortex lesions, particularly the right side, may cause deficits in the recognition of facial emotions and prosody.

As for the lack of recognition of facial expressions of disgust, neuroimaging studies have shown that the expression of disgust activates the following brain areas: the insula, the putamen and the head of the caudate. Patients with Huntington's disease, in which these areas are atrophic, show particular difficulties in the recognition of these facial emotion; it has recently been shown that in such patients the impairments in the recognition of facial expressions of disgust are associated with difficulties in the recognition of a voice expressing disgust, of smell and classification of disgusting figures, as well as knowledge of what causes disgust; all these observations confirm the hypothesis that the insula-striatal system is involved in the elaboration of disgust irrespective of the modality of stimuli presentation (Benussi, Nichelle, 2007).

Some research in patients with gelastiche epilepsy showed that there is independence of facial expressions from emotional experience: the emergence of crying and laughter behaviour in these patients is never accompanied by an emotional experience congruent with the manifested expression (Poeck, 1985). Similarly, the reduction of facial expressions in patients with Parkinson's disease is accompanied by an emotional experience at all comparable to that of control subjects (Rinn, 1984). Neuropsychology has also led to a specific contribution with respect to the recognition of emotional tones, and even in this case, the results seem to confirm the modular organization of the emotional process. The individual can use prosody to convey linguistic or emotional information; with regard to the former, a left hemispheric specialization has been shown, while for the prosodic emotional information the right hemisphere plays a dominant role.

Right fronto-parietal lesions lead to disturbances in the production of emotional tone, while left posterior temporal lesions cause a disturbance in the ability to discriminate between different emotional tones, as well as with aphasia (Ross, 1984).

CHAPTER 3

INTERACTIONS BETWEEN EMOTION AND ATTENTION IN MODULATING HUMAN BEHAVIOUR AND PERCEPTUAL PROCESSES.

3.1 Modulation of visual attention by means of meaningful (fearful) emotional stimuli: evidences in normal subjects and brain damaged patients.

"What is the relationship between attention and perception? How much, if anything, of our visual world do we perceive when we are not attending to it? Are there only some kinds of things we see when we are not attending? If there are, do they fall into particular categories? Do we see them because they have captured our attention or because our perception of them is independent of our attention?"

This interesting and meaningful question has been posed by Arien Mack & Irvin Rock, in their book, "Inattentional blindness" (1998), a phenomenon characterized by the inability to perceive something caused by the fact that subjects is not attending to the stimulus but instead is attending to something else. In order to explain this phenomenon, the Authors describe some experiences of being totally absorbed by an activity, such as a conversation, so that very little from the external world seems to be perceived.

On the opposite, they refer the very particular experience, i.e.. when we are expecting to see something specific to happen and we then see or hear things that are not really present.

With regard to the first example, the inhibition of attention has been shown to happen in experimental tasks, thanks to the manipulation of attention, by means of instruction, stimuli spatial locations and so on.

By assigning to the term "perception" the meaning of "explicit conscious awarness", distinct from implicit perception, the Authors conclude that there is no perception without attention, then following that anything that is perceived must be perceived because attention is engaged. If some critical stimulus is perceived in our inattentive condition, it must be because it has captured or attracted attention; there might be some visual stimuli that would capture attention reliably even under conditions in which other stimuli went undetected.

These considerations remind to a concept of attention, and perception, as very flexible phenomena.

Human behavior, to be adaptive, must be based on a brain dealing with two opposite demands: the selection of goal-relevant stimuli for privileged processing by mechanisms of attention, but also the detection of potentially significant events that may occur unpredictably outside the focus of attention.

Mammals evolved in environments where resources and dangers were unpredictably distributed in space and time. The ability to efficiently locate critically important events in the surroundings was an important aspect of the reproductive potential of individuals. Resources such as food and mating partners were the objects of active foraging, whereas dangers had to be reflexively detected to be adaptively avoided. Framed in this way, two different kinds of selective attention enter the adaptive problem. Following James (1890), researchers have commonly distinguished between active and passive attention. The former is conceptualized as goal-driven and voluntarily (top-down) controlled, whereas the latter is stimulus driven, governed by (bottom-up) perceptual processes.

Some Authors also postulated an important distinction between preattentive and postattentive visual attention: the former is fast, automatic, and works in parallel on low-level stimulus features, with the primary aim of *delineating objects* in the spatial surrounding. The latter is slow, deliberate, and serial and is concerned with more complex inferential and interpretative processes in *identifying the located objects* in perceptual awareness (e.g., Posner, 1978; Treisman, 1988).

Thus, goal-driven processes would be involved by mammals in looking for food, while stimulus-driven attention would be aimed at detecting threat.

James (1890) included threatening events such as "wild animals," "metallic things," "blows," and "blood" among stimuli likely automatically and reflexively to capture attention.

According to this theory, there are some meaningful stimuli which are able to summon attentional processes “by default” (Folk et al., 1992), even when we are not attending to them and when objective limitations in our attentional system are present, because of survival relevance. Thus, evolution may have adaptively selected stimuli related to recurrent threats in the environment to become more or less automatic triggers of attention (Tooby & Cosmides, 1990).

According to these hypothesis, some studies, performed in the last twenty years, demonstrated psychophysiological responses to fear stimuli (snakes, spiders, and angry faces) that were blocked from conscious processing because of backward masking (Dimberg & Ohman, 1996; Ohman & Mineka, 2001).

Many studies examining the cognitive effects of emotion have adapted and employed paradigms extensively used in the literature on attention, such as visual search (Eastwood et al., 2001), exogenous orienting (Mogg et al., 1994, 1997), inattentional blindness (Mack and Rock, 1998), or Stroop interference (Mathews and Klug, 1993).

Ohman et al. (2001), presented their research participants to two fear-relevant (snakes and spiders) and two fear-irrelevant (flowers and mushrooms) categories of stimuli. The task was to detect discrepant stimuli in matrices of pictures, either composed only of exemplars from the same category (e.g., flowers) or including a single target exemplar from a different category (e.g., a snake) among those of the background category (e.g., flowers). Their hypothesis was that participants would be faster to detect fear-relevant discrepant stimuli among fear-irrelevant visual stimuli than vice versa and that this effect should be independent from the number of distractors, according to a “pop out” effect of threatening stimuli (see paragraph 1.3). They also compared the performance of participants fearful of snakes or spiders with nonfearful participants. The underlying assumption here was that intense fear of a category of stimuli would modulate the attention control setting (Folk et al., 1992) to make stimuli from this category more salient in automatically grabbing attention.

Ohman et al. found that fear relevant pictures were detected more quickly than fear-irrelevant ones. Fear-relevant, but not fear-irrelevant, search was unaffected by the location of the target in the display and by the number of distractors, suggesting a parallel search for fear-relevant targets and a serial search for fear irrelevant targets. Then, participants specifically fearful of snakes but not spiders (or vice versa) showed facilitated search for the feared objects but did not differ from controls in search for nonfeared fear-relevant or fear-irrelevant, targets. Thus, evolutionary relevant threatening stimuli were effective in capturing attention.

In line with the previous study results, specific attentional bias have been found under condition of inattention to target stimuli, related to subjective psychological and emotional aspects, such the presence of specific phobia or anxiety disorders (see for example Martin M. et al., 1991; van den Heuvel OA, 2005),

Hermans D. et al. (1999) investigated a more detailed aspect of this attentional bias, such as its temporal course, by using the on-line registration of eye movements, as a continuous index of attention deployment towards emotionally relevant (spiders) or irrelevant (flowers) material. Results showed that participants with specific phobia for spiders looked significantly more at spiders than at flowers during the beginning of the stimulus presentation, but subsequently their viewing pattern shifted more and more away from the spiders. Control participants showed a more stable pattern as they looked more at spiders than at flowers throughout the trial.

Vuilleumier and Schwartz (2001) investigated the capacity of threat-related stimuli to summon spatial attention under a condition of inattention, such unilateral spatial neglect with extinction of controlateral presented stimuli. They hypothesized that patients were more likely to perceive fear-relevant pictures presented in their left (contralesional) hemi-field than other visually similar pictures.

Stimuli were black outline drawings of spiders, flowers, or ring shapes with four possible exemplars in each category; spider and flower stimuli shared exactly the same visual features, so that any difference in perception for these stimuli could not be confounded by some differences in their low-level visual attributes, e.g. degree of contrast or brightness. All unilateral and bilateral stimuli were equally probable.

The critical experimental trials were bilateral displays with left spiders vs left flowers. All trials began with a fixation cross at the center of a computer screen, followed 800 ms later by stimuli presented on the right, left, or both sides in a random order. The patients had to identify and locate the stimuli on each trial. Results showed that, on bilateral trials, the patients detected emotional stimuli (spiders) on the left side much more often than neutral pictures (flowers).

This study provided direct evidence for an advantage of threatening stimuli in visual processing and access to conscious awareness.

3.2 Facial expressions as emotional cueing: rational and empirical evidence

Arien Mack & Irvin Rock (1998), in their investigation about inattentional blindness and stimuli capable to overcome this effect, found that a cartoon-like happy face is generally perceived and identified under conditions of inattention. On the contrary, they found that a scrambled or sad version of the face generally will not be seen without attention. The Authors explain this effect as due to a high level of familiarity of the first stimulus.

In the course of the last ten years, emotionally expressive faces, bringing a negative (such as fear and anger) or positive (happiness) expression, have been largely employed to study the role played by emotional stimuli in modulating spatial attention. Several studies have established the importance of the amygdala in mediating responses to fear-eliciting stimuli, and have suggested that it might play a critical role in the modality detection of these stimuli.

Morris et al. (1996) performed a positron-emission tomography (PET) measure of neural activity while subjects viewed photographs of fearful or happy faces, varying systematically in emotional intensity. The neuronal response in the left amygdala was significantly greater to fearful as opposed to happy expressions. Furthermore, this response showed a significant interaction with the intensity of emotion (increasing with increasing fearfulness, decreasing with increasing happiness). The findings provide direct evidence that the human amygdala is engaged in processing the emotional salience of faces, with a specificity of response to fearful facial expressions**.**

Villeumier performed several studies investigating the psychophysiological, temporal and neuro-anatomical correlates of the modulation of attentional processes by means of emotional stimuli, even when not consciously perceived or intentionally attended (see for example Villeumier et al., 2001, 2003, 2004).

Villeumier et al. (2001) used event-related functional magnetic resonance imaging (fMRI) to examine whether neural responses to emotional face stimuli are affected by a manipulation of spatial attention in healthy subjects. In particular, they wanted to determine whether processing of fearful expression in faces can occur even when attention is directed elsewhere for a demanding task and to assess whether the degree of such processing is modulated by attentional condition. Attention was manipulated in terms of whether stimuli appeared at task-relevant or task-irrelevant locations and facial expression were considered as independent factors.

Participants were presented with arrays consisting of two faces and two houses arranged in horizontal and vertical pairs (see Fig. 3.1). The location of face and house pairs (vertical versus horizontal) and emotional facial expression (fearful versus neutral) varied randomly across trials. Participants were required to attend either to the two vertical or to the two horizontal locations (as indicated by a precue presented at the beginning of each trial), in order to detect and respond to infrequent target stimuli (two identical photographs) at cued locations. Stimulus pairs at uncued locations could be entirely ignored.

Results showed that whereas the fusiform gyrus response to faces was strongly modulated by the condition of spatial attention (i.e., when faces appeared at task-relevant versus task-irrelevant locations), the left amygdala response to fearful expressions was not affected by this manipulation. Right fusiform gyrus activity was also influenced by emotional expression, with a greater response to fearful than neutral faces, in addition to the effect of attention at this site. By contrast, some cortical and subcortical regions showed a differential engagement by emotional faces as a function of the attentional condition, including the anterior temporal cortex, anterior cingulate gyrus, orbitofrontal cortex, and ventral striatum.

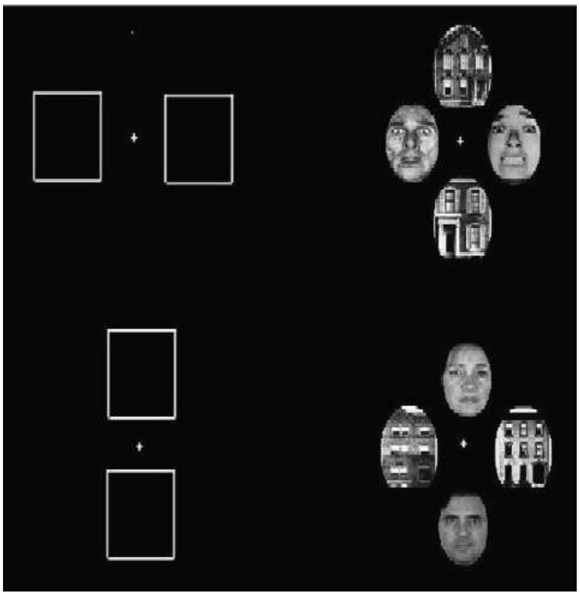


Fig. 3.1 From Villeumier et al. (2001): "…*illustrations of stimulus presentation procedure used in the experiment. Each trial started with a cue (80 ms duration) directing attention to two horizontal (top left) or two vertical positions (bottom left). 720 ms after cue offset, a stimulus array consisting of two houses and two faces was presented for 300 ms. Face pairs were presented horizontally, and houses vertically (top right), and faces were either fearful (top right) or neutral (bottom right). The figure shows non target trials with non-identical fearful faces (top) or neutral faces (bottom) at cued (attended) locations. In target trials, identical stimuli were presented at cued locations*…".

In a following study, Holmes, Villeumier et al. (2003) employed the same task described above by performing an event-related brain potential (ERP) analysis, in order to deepen the time course of emotional processing in response to fearful faces.

To investigate effects of spatial attention on face-specific processing stages, ERPs elicited on faces-cued trials were compared to ERPs obtained on houses-cued trials, where faces were task-irrelevant and could be completely ignored.

Results showed that, when faces were attended, a greater frontal positivity in response to arrays containing fearful faces was obtained, starting about 100 ms after stimulus onset. In contrast, with faces located outside the attentional focus, this emotional expression effect was completely eliminated. The conclusion that ERP modulations sensitive to emotional facial expression are gated by spatial attention appears to contrast with results from the previously described fMRI study from Villumier et al. (2001). However, the Authors argue that the recorded ERPs could arise from subsequent neocortical stages of emotional processing (as in temporal pole, anterior cingulated gyrus and orbitofrontal cortex) dependent on focal attention, while amygdala activations in response to emotional stimuli are unaffected by attentional selectivity.

Villeumier et al. have examined the effect of emotional versus neutral cues on spatial orienting of attention toward peripheral visual targets, following the classical paradigm developed by Posner et al. (1982). Orienting has been shown to be faster to targets appearing on the same side as an emotional cue (e.g., faces, spiders, threat words) and slower to those appearing on the opposite side (Armony and Dolan, 2002; Mogg et al., 1994, 1997). In some cases, disengaging from invalid cues to reorient elsewhere appears to be especially slow when such invalid cues are emotional, suggesting that attention is not only captured but also tends to dwell longer on emotional stimuli (Fox, 2000). Similar effects can occur even when emotional cues are masked and not consciously perceived (Bradley et al., 1997).

Villeumier et al. (2004) designed a covert spatial orienting task, basing on classic Posner's paradigm, while recording visual event-related brain potentials (VEPs): on each trial, two faces were briefly presented, one in each visual field, one neutral and one with an emotional expression (fearful or happy). The two faces were then replaced by a small bar-probe at the position just occupied by one of them, oriented either vertically or horizontally. Participants were asked to judge the bar orientation as quickly as possible. The bar unpredictably appeared on the side of the emotional face (valid condition) or on the side of the neutral face (invalid condition), but importantly, both neutral faces and emotional expressions were entirely irrelevant to the participants' task (see picture 3.2).

VEP results showed that neural responses to a bar-probe were enhanced when the preceding face pair displayed a fearful stimulus at the same location. These VEP effects were demonstrated by a greater amplitude of the lateral occipital P1 component on valid versus invalid trials. This increased P1 response to the bar-probes was independent of the side of the fearful face or the side of the bar, but occurred specifically when the bar replaced the location of a fearful face. Furthermore, such an exogenous spatial validity effect was not found following happy faces, as shown by a significant validity × emotion interaction on the mean amplitude of P1. These results suggest a dissociation between fearful versus happy faces in their capability to capture spatial attention in an exogenous way.

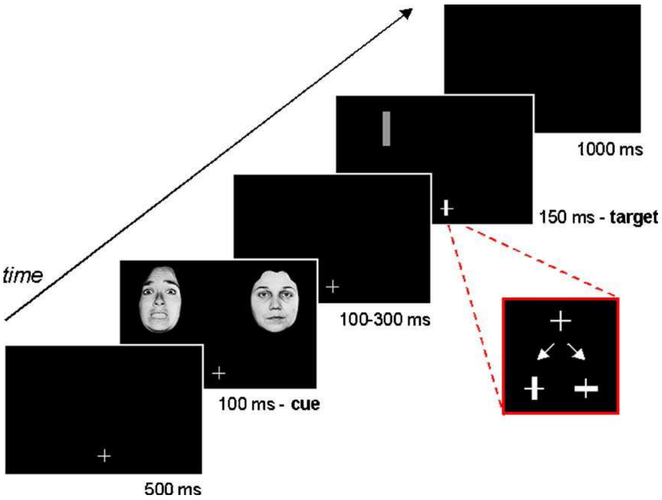


Fig. 3.2 From Villeumier et al. (2004): paradigm used in the fMRI experiment, showing the sequence of events within a trial. *"A dim gray bar (target) could unpredictably appear in the upper visual field on either side, following a pair of faces in which one had a neutral expression and one an emotional expression (fearful or happy). The face-target interval was randomly jittered between 100 and 300 ms. At the time of target onset, the vertical or horizontal segment of the fixation cross was slightly thickened to indicate the relevant orientation to be monitored for targets. Participants had to make a two-alternative (same/different) judgement on the orientation of the peripheral target relative to the thick cross segment (match in the 50% trials). A target could appear on the same or opposite side as the preceding emotional faces (valid or invalid trials, respectively; equally probable) or was not presented on a third of trials (cue-only trials). Faces were by themselves always irrelevant to the task"*.

In a successive work (Villeumier, 2006), the same paradigm was employed in order to identify brain mechanisms involved in the modulation of spatial orienting by negative (fearful faces) or positive (happy faces) stimuli. fMRI results showed that laterally presented fearful faces, as opposed to happy faces, may act as exogenous cues on spatial attention by modulating activity in a network of brain areas, including parts of the dorsal and ventral cortical systems previously associated with the control of attention for non-emotional stimuli, as well as extrastriate visual areas, but also involving other regions potentially specific to emotional processing. In particular, an initial stimulus-driven response in inferior and posterior TPJ to salient cues, with a subsequent interaction with more superior areas in IPS to focus attention on relevant locations and enhance sensory processing in extrastriate visual areas (Hillyard et al., 1998; Carrasco et al., 2000; Pourtois et al., 2004). Other areas in OFC and lateral prefrontal cortex might be more specifically implicated in regulating the allocation of processing resources in the presence of conflicts or distractors, based on current motivational and goal-driven signals.

The strenght of these results has been proved also in clinical sample of subjects, recruited on the basis of the presence of neurological disease leading to a reduction in perceptual awareness, such as neglect and cortical blindness.

Villeumier et al. (2001) showed that, if neglect patients are briefly presented with shapes or faces with neutral, happy, or angry expressions in the right, left, or both visual fields, they extinguished faces in the contralesional field much less often than shapes, and faces with happy or angry facial expressions much less than faces with a neutral expression (Vuilleumier, Schwartz, 2001). These results showed that facial features and emotional expression, differently from other neutral stimuli, can be processed despite presented in the neglected hemispace, and can modulate allocation of spatial attention resources.

Tamietto et al. (2005) administered to one patient with unilateral spatial neglect and four right brain-damaged controls a line bisection task with pictures of neutral and emotional faces as unilateral cues; they thus manipulated the attentional salience of the cues (higher for emotional and lower for neutral faces) while keeping constant their physical dimensions.

What they observed was an effect of cue manipulation evident for both neglect patient and right brain damaged control subjects, with left cues reducing, and right cues increasing the bisection bias.

However, effects were different in the two samples: in control subjects with right hemisphere lesions, the specific content of the cues did not affect line bisection either with left of right cues. In patient FM, by contrast, left happy and angry faces were more effective than left neutral faces in reducing the rightward directional bias. Importantly, the modulation of emotional faces on line bisection was confined to the left (neglected) hemispace and occurred even though the content of the cues was irrelevant to the task.

Later, Villeumier et al. (2008) developed a visual search task paradigm in which right brain damaged patients with neglect and healthy participants had to report the gender of a target face, whose identity was unique amongs an array of distractors with a different identity. Distracter faces were always neutral. Critically, the target face could differ from the distractors by identity alone (neutral baseline), by identity plus expression (fearful or happy), or by identity plus colour (red hue). In a way similar to healthy subjects, neglect patients exhibited significant cueing benefits with both the colour and expression of faces. Thus, although generally slower in finding target faces on the left than the right side, patients were faster to detect a face with a different colour or a different expression, relative to a face with similar colour and neutral expression as the distractors, regardless of target side.

Interestingly, in both groups the emotional influence over attentional processes arised both from positive (happy) and negative (fearful) emotional expressions.

As reported by the Authors, these findings go beyond previous results showing reduced visual extinction for emotional stimuli in neglect patients (Vuilleumier & Schwartz, 2001) or affective priming with extinguished contralesional emotional faces (Williams & Mattingley, 2004), by demonstrating that such emotional effects can operate in a difficult search task with a more cluttered visual scene and many competing distractors.

Another category of neuropsychological disturbances where the study of facial expressions has provided interesting results is prosopoagnosia, characterized by a deficit in the face identification.

Villeumier et al. (2009), by studying a patient with acquired prosopoagnosia, found a facilitation effect in a visual search task, similar to that observed in healthy subjects, with attention preferentially directed towards emotionally expressive faces. These results suggest that emotional expression can guide visual attention to faces, also modulating fMRI activity in right fusiform gyrus, in a rare patient with acquired prosopagnosia.

These findings provide evidence for a distinction between brain systems responsible for attentional orienting to facial expressions and brain systems underlying face identification.

In the next paragraph, the mechanisms underlying the cueing effect of emotional stimuli are discussed, according to recent literature.

3.3 Modulation of visual processing by attention and emotion: causal interactions between different brain regions

The studies described in the previous paragraph show that attention is a multidimensional and adaptive process, and that emotional stimuli can readily summon spatial attention, even if not relevant for the task to be performed.

Neuroimaging studies using PET or fMRI (see for example Villlumier 2001) have shown enhanced responses to emotional stimuli relative to neutral stimuli arising in category-selective areas, such as the fusiform face area (FFA) for emotional faces, and in posterior occipital and parietal regions. Besides, increased sensory responses involving early components have been recorded during the presentation of such stimuli, reflecting a not explicit orientation.

Similar increases are seen in auditory cortex for emotional sounds or voices (Mitchell et al., 2003). Differently, during tasks requiring more explicit evaluation of affect, stronger or additional activations are recorded, particularly in higher-level brain regions (superior temporal sulcus or ventromedial prefrontal cortex), reflecting more complex appraisal processes.

For these reasons, two different source of top-down modulation of sensory processes can be identified. The first is the selective attention activated for task-relevant stimuli (endogenous source regulated by inner goals), by higher-level regions (frontal and parietal areas). Attentional effects exerted by frontal and parietal regions upon visual perception and visual awareness are clearly observed in patients with brain damage referred to these cerebral areas, like the “spatial neglect” syndrome.

Another important source of modulation of sensory processing, which is the main argument of this discussion, arises mainly from amygdala, and is related to the affective value of perceived stimuli. As we described in the previous chapter, amygdala, an almond-shaped nucleus in the anterior medial temporal lobe, is crucial in fear processing and fear learning, but is also presumably important for a wider range of functions related to affective pertinence and reflexive emotional reactions.

Amygdala has extensive interconnections with many cortical and subcortical regions, including primary visual cortex.

As described above, experimental works, in particular Villeumier & coll.’s (2001), have showed that amygdala activity correlates with enhanced responses to emotional stimuli in visual cortex. Connectivity analyses also reveal a greater “coupling” of amygdala with fusiform gyrus and primary visual cortex when seeing fearful vs neutral faces.

Besides, further evidences come from study employing patients with amigdala lesions and intact visual areas, showing the deletion of these enhanced visual activations for fearful faces: patients with hippocampus damage but intact amygdala show normal increases for fearful faces in visual cortex, whereas patients with amygdala damage show no such increase.

The severity of amygdala lesions is inversely correlated with fusiform enhancement in the same hemisphere, consistent with a role of ipsilateral connection between amygdala and cortex.

An important question regards the relations that interplay between emotional and attentional modulation of visual processes. An interesting hypothesis suggests that emotional modulation arising from amygdala could give to particular stimuli (those with affective significance) an added “competitive strength” in neural representations, against other incoming stimuli (Desimone & Duncan, 1995; Kastner & Ungerleider, 2001), like those task-relevant.

However, some studies showed that, under particular circumstances (such as a high attentional loud) the amygdala response can result not strong enough to overcome attentional modulation, so that response to emotional stimuli can be reduced.

Emotional and attentional modulations probably arise from separate causal sources. Empirical evidence of an additive effect of emotion and attention over sensory perception arise from Villeumier et al.’s fMRI study (Villeumier, 2004), where both factors were manipulated separately: the fusiform face area was more activated when faces were shown at task-relevant locations, rather than at other locations; besides, and significantly, fusiform face area was also more activated by fearful than neutral faces, even when faces were task-irrelevant. This strongly suggests that amygdala influences visual cortex additively, over and above concomitant modulation by voluntary attention.

Further evidence of separated causal source and effects for emotional and attentional modulation arises from studies about patients with unilateral spatial neglect and extinction consequent to right parietal damage. In such patients, an effect of amygdala over visual perception has been detected, with an activation evoked by fearful faces in fusiform cortex, both when consciously seen and in absence of awareness. These results suggest that emotional modulation of visual processing can partially compensate for reduced attention due to parietal damage, supporting an additive effect of emotion and attention as observed in healthy subjects.

Different routes might provide sensory information to amygdala, even when conscious perception, related to cortical processing, is reduced. A two-pathway hypothesis suggests a role of subcortical inputs, probably through the superior colliculus and the pulvinar; in such way, amygdala response to emotional stimuli could persist even in patients who are blind do to a cortical damage destroying visual cortex. Dolan and Villeumier investigated this hypothesis in a patient, GY, who, due to a traumatic damage to the left occipital cortex, was blind in the contralateral right visual field (Dolan & Villeumier, 2003). By carrying on several event-related fMRI studies during the execution of visual search tasks involving emotional faces, the Authors found a greater covariation between activity in the amygdala and in the pulvinar and culliculus for blind-field presentation of fearful faces.

Alternatively, a two-stage hypothesis suggests an initial feedforward sweep through the visual system before complete processing; thus, an initial appraisal of emotional significance might take place in the amygdala based on a limited amount of information.

However, amygdala is not the only source for emotional modulation of sensory processing: orbitofrontal cortex and the striatum also play an important role in emotional/motivational modulation of sensory processing.

Besides, some evidences support the modulation of parietal neurons by reward-related information, arising from cerebral areas implicated in motivational processes, such as the amygdala, the orbitofrontal cortex and the striatum, suggesting a link between rewards and attentional systems. The orbitofrontal cortex has bidirectional connections with the amygdala, also projecting to parietal and lateral prefrontal areas (see chapter 2); in such a way, reciprocal interactions between dorsolateral and ventral regions in prefrontal cortex can be supposed, with ventral regions activated by emotional distractors and deactivated by task-relevant neutral targets and dorsal areas being activated by task-relevant targets but deactivated by emotional distractors.

So, these two systems might interact in the re-allocation of processing resources and in the determination of behavioral goals.

3.4 Emotional cueing by means of bodily expressions: conceptual basis and empirical evidence

In an intriguing recent article, De Gelder (2009), a researcher of the affective neuroscience field, questions about why bodily expressions has not received so much attention as facial expressions to this day.

The Author analyzes one of the main issues against body expression study, which claims a more immediate recognition of facial expression, as proposed by Ekman theory; she highlights that available researchs show that recognition performance for bodily expressions is very similar for face and body stimuli, both for static and dynamic whole-body stimuli.

Later, De Gelder discusses a possible socio-cultural origin of the bias in favor of facial expressions. With an interesting interdisciplinary perspective, the Authors cites Descartes's approach, stating the dualism between mind (soul) and body problem, which has influenced medical and scientific approach to human beings till nowadays.

"If dualism represents the notion that there is a seemingly unbridgeable gap between our mental life and our material existence, then the face falls on the side of the mind and mental life while the body is relegated to the realm of the machine. The face expresses the

mind, but the body, as is typical of machines, does not have a mind of its own and thus does not express anything. Just as the movements of a car do not express the car's feelings or intentions, the movements of the body are equally mechanistic and devoid of meaning" (de Gelder, 2009).

In opposition with this Cartesian view of emotions as private mental episodes, Darwin argued that emotions are adaptive in the sense that they prompt an action that is beneficial to the organism, given its environmental circumstances. In such perspective, both facial expressions, emotional body language (EBL) and vocalizations consist of specific actions performed in order to reach a goal, with a strong link between emotion and action.

From a comprehensive and global perspective, faces and bodies are comparable because they both convey information that is essential for social interaction.

Yet, some important differences can be identified, with regard to the way they play this role. It seems likely that faces are used for fine-grained analysis of communication intention and possibly also convey a broader range of subtle emotions in a setting of close-by person to person. In contrast, while body language is still important for close-by interaction, bodily expressions allow for appraisal of action intention and emotions over larger distances.

"…A major consequence of these considerations is that bodily expressions can be recognized from far away while the face expressions require the viewer to be nearby…" (de Gelder, 2009).

Bodies convey a large amount of information related to actions and goals of behaviour, more than a person's mental state. This distinction reminds, in the philosophical field, to two main different approaches to emotional experience: an emotional state as an inner object, located inside the subject mind, or as an overt experience, visible through subjects actual movements and actions in the ongoing world.

An important question in the study of facial expressions, and thereby in that of body expressions, is whether visual recognition of these emotional languages involves the detection of the overall structure, as it should be for preferred stimuli in the human perception system; another relevant issue regard as if a dedicated neural system is present for the elaboration of these aspects of human behavior.

As for the former, many evidences have proved that both faces and bodies involves a configurational perception: in the first stages of face, as well as body perception, the brain is tuned to extracting the overall configuration rather than the details, as showed by study investigation of face and body inversion effects.

This effect is assessed by measuring the perceptual processes triggered when the stimuli are presented upside down. The resulting difference in performance is called the inversion effect, which refers to the loss of performance when faces have to be recognized from upside down compared with upright presented stimuli. This effect is not specific for faces, in fact a similar loss of performance is also observed for other stimuli such as landscapes. Recent findings show that the recognition of faces and bodies presented upside down is relatively more impaired than the recognition of inverted objects (such as houses) when each category is compared with its own inverted counterpart (Reed et al. 2003).

The other important issue regard what areas in the brain respond to bodily expressions, if they are the same or different with respect to facial expressions.

The neural network underlying face perception is well known and includes the fusiform face area (FFA) (Kanwisher et al., 1997), the occipital face area (OFA) (Gauthier et al., 2000; Puce et al., 1996), the STS and the AMG (Haxby et al., 2000). Recent studies indicate that the neural network underlying whole body perception partly overlaps with the face network (de Gelder, 2006; de Gelder et al., 2010; Peelen and Downing, 2007).

Some studies, relative to brain regions selective for bodies, compared fMRI responses to images of bodies without faces and body parts. This approach has found that a focal region of the lateral occipital-temporal cortex responds strongly and selectively to static images of human bodies and body parts, but weakly to faces, objects and parts of objects. Based on other findings this region has been labeled as extra striate body area (EBA). The EBA is located bilaterally in the inferior posterior parietal sulcus and the medial temporal gyrus.

Recent studies with fMRI showed the existence of a second selective area for bodies that is anatomically distinct from EBA (Peelen & Downing, 2005). This region is located in the fusiform gyrus and is known as the fusiform body area (FBA) and selectively responds to all bodies and body parts, as in the schematic representations of bodies. The FBA is partly overlapping and adjacent to the selective region for the faces, the fusiform face area (FFA). Furthermore, a study of high-resolution fMRI found small parts of the fusiform gyrus that were selective for bodies but not their faces, and vice versa.

A key question is whether the EBA and FBA can be dissociated with regard to their functional properties. A recent study on responses to images of bodies of different types (fingers, hands, arms, torsos, whole bodies) found a higher selectivity than in EBA for body parts, and a relative error (bias) in selectivity of the most complete pictures of the body in the FBA. The findings suggest a possible distinction between these two areas, with the analysis of bodies in EBA focused on an individual part, and the function of the FBA to create a holistic, overall (Pelen, Downing 2007).

The first brain imaging study of EBL with realistic body stimuli (Hadjikhani & de Gelder, 2003) used fearful and happy EBL images, each of which was compared with images of neutral whole-body actions (for example, getting dressed or opening a door). Fearful bodies activate the two main areas associated with the processing of facial expressions of fear, i.e. the amygdala and the right middle fusiform gyrus. When we see neutral, fearful or happy whole-body expressions with the facial expression blurred, fear images activate these areas. The similarity between perception of facial expressions and EBL extends to temporal dynamics. Recent studies show that we process bodies as rapidly as faces, and perceive the same properties of both facial and body stimuli. This is shown by the finding that body images produce the N170 (a waveform in the electroencephalogram (EEG) with negative amplitude that peaks about 170 ms after stimulus presentation), which was originally viewed as the first temporal marker of face-specific processing. It seems that the initial facial and body image processing stages are probably similar as these stimuli elicit comparable amplitude, latency and scalp distribution of the N170. Evidence suggests that objects are not processed in the same way, as control objects did not generate a N170.

However, these results, which confirm the involvement of AMG, FG and STS in both face and body perception, have been obtained by using static images (Meeren et al., 2008; van de Riet et al., 2009) which may only imply motion; however, explicit movement information in dynamic stimuli may activate a richer and partly different, broader network.

A study employing dynamic neutral and threatening face and body expression showed that the AMG was modulated more by faces than bodies. A number of crucial areas showed higher activation for bodies than for faces and some reflected affective stimulus meaning. Body specific activation increases were found in the FG, EBA, superior parietal lobule (SPL), primary somatosensory cortex (SI), thalamus, and temporoparietal junction (TPJ). TPJ and FG showed more activity while processing emotional faces and bodies than neutral ones. There was an interaction between category selectivity and emotion in EBA and in STS. This area was specifically modulated by threatening body expressions. So, whereas EBA and STS show a specific activity pattern triggered by emotional bodies, FG is equally responsive to emotional faces and bodies (Kret et al., 2010).

In the previous paragraph, a part of the extensive literature describing implicit (i.e. nonconscious) processing of facial expressions (de Gelder et al., 2001a; Eastwood & Smilek, 2005; Vuilleumier, 2005) has been presented.

As we have discussed, nonconscious processing of emotional behaviours may occur either because attention is engaged elsewhere, so that the unattended stimulus goes undetected (as showed in healthy subjects studies), or because conscious vision is directly prevented (in spatial neglect and cortical blind patients).

Some studies showing that facial expressions can be elaborated under conditions of limited attention and awareness have provided significant support to the view that faces have a special status. Recent evidence now shows a similar situation for bodily expressions. Two separate lines of evidence are provided by studies of neurological patients with attention disorders or with cortical blindness.

In patients with hemi-spatial neglect following lesions to the right parietal cortex, it has been previously shown that emotional facial expressions presented to the left side tend to call for attention and are more often detected than neutral faces or objects, therefore partially overcoming the attentional bias (Vuilleumier & Schwartz, 2001; Vuilleumier, 2002; Tamietto et al., 2005). Tamietto have replicated this effect by showing that also fearful bodily expressions may automatically summon spatial attention towards the neglected side, even under more stringent testing conditions than those previously used with faces (Tamietto et al., 2007). Indeed, the brain structures known to be implicated in the perception of human bodies, in recognition of emotion and in action representation, are generally intact in patients with visual extinction and neglect, in particular the fronto-limbic circuit (including OFC and the amygdala) and visual areas.

However, some differences can be highlighted with regard to the neural correlates of conscious versus nonconscious processing of faces and bodies in neglect patients. In fact, in the case of faces, a fronto-limbic system seems to be primarily involved in attentional recall and in restoring stimulus awareness (Vuilleumier, 2002), while sensory-motor and interoceptive areas (e.g. insula) appear more critical with regard to bodies (Tamietto et al., 2008).

De Gelder et al. (2006), by reviewing the way how emotion from EBL is processed in the brain, proposed a ‘two-systems’ model of emotion–behavior connectivity.

In this model, amygdala is placed at the center of two separate emotional circuits, composed by an automated circuit, relying on subcortical structures, and a cortically controlled circuit, which works in a less automatic and in a more deliberated way (see Fig. 3.3).

The primary network is composed of the superior colliculus, pulvinar, striatum (putamen and caudate) and basolateral amygdala; this subcortical route sustains the rapid automatic perception of EBL and preparation of adaptive reflexes, with some similarities with what has been proposed for non-conscious recognition of faces, but with stronger and more direct connections with motor structures.

The second system consists of a cortical network with reciprocal connections to the primary circuit. This system includes the frontoparietal motor system, and connections between the amygdala and the prefrontal and ventromedial prefrontal cortex have a major role in the processing carried out by this system. The main role of the second system, according to past experience and memory, is to perceive EBL in detail, to compute the behavioural consequences of an emotion and to decide what to do in response to the stimulus; typically, the action is determined by the stimulus eliciting the bodily reaction (for example, fear expressed during running).

Both systems are connected with brain structures, playing a role in connecting awareness of bodily states to decision making. The two input systems also have numerous interconnections, but can also function in part autonomously, so that an alerting event detected in the subcortical pathway can elicit a rapid reflex-like reaction, even in absence of detailed stimulus processing.

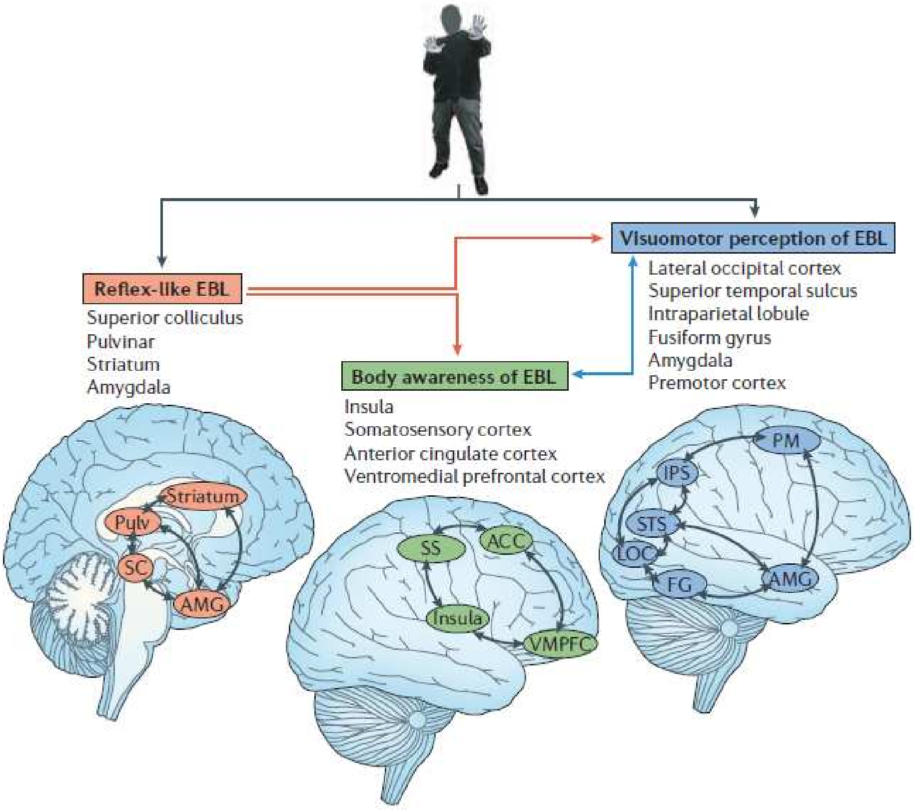


Fig.3.3 The De Gelder “two-systems” model of emotion–behavior connectivity

3.5 Emotion and motor programs: correlation between amygdala and motor neuron activity in emotional experience

Together, the discussed results show that, in addition to modulate sensory and emotional regions, the perception of actions expressing a threat is associated to increased responses in brain regions associated to motor preparation (Hoshi & Tanji, 2004) and defensive responses (Graziano & Cooke, 2006).

Besides, a well known phenomenon, the spontaneous tendency to synchronize our facial expressions with those of another person during face-to-face interactions, named “emotional contagion”, provides support to the link between emotion and motor activity.

In an extreme perspective, James–Lange argued that the subjective experience of emotion is a byproduct of the motor activity elicited by the stimulus.

The recent discovery of mirror neurons again put attention to motor structures. “Mirror neurons”, in the ventral premotor cortex area F5 and in the parietal area 7b, fire when an animal performs a given action, as well as when the same action is observed.

Functional neuroimaging provides evidence that humans have similar mirror neurons. Based on these findings, it has been proposed that mirror neurons are the basis of social cognition.

Studies about patients with autism show a reduced activity in the mirror neuron system when they passively observe or actively imitate facial expressions; these observations can be explained with a reduced cortical thickness in mirror neuron brain areas in autism; another possible explanation suggest a deficit in the amygdala, which could cause poor connectivity to superior temporal sulcus and premotor cortex structures, then turning into a less activation of motor representation.

This last explanation reminds to an interesting issue, namely the relation between the amygdala and the motor system. An hypothesis substains that in human beings it could be that the motor neuron activity spreads to the amygdala; in such perspective, emotional contagion should be based on perception of movement and mimicry. According to this view, we react to the facial expression seen in others with the same expression in our own face because the perception of an action prompts imitation in the observer; this process thereby implies a direct motor matching between the effectors perceived and those activated by the observer (motor resonance). An alternative explanation considers emotional contagion as an initial marker of affective, instead of motor-mimetic, reactions that unfold because the detection of an emotional expression induces in the observer the corresponding emotional state.

Tamietto et al. (2008) investigated the relation between emotional contagion and motor imitation in a sample of patient with reduced perceptual awareness, due to cortical blindness, by recording facial reactions (with electromyography) and arousal responses (pupil dilatation) while exposing them to pictures of facial or bodily expressions to both the intact or blind visual field. Results showed that the patients did not simply imitate the motor pattern observed in the stimuli, but reacted to their affective meaning, by supporting the idea that emotional contagion is not dependent from motor resonance.

However, the role of motor resonance is not excluded at all; motor resonance may facilitate emotional contagion responses, but critically depends on perceptual awareness and cortical vision and comes into play only after nonconscious perceptual structures that bypass visual cortex have evaluated the affective valence of the stimuli.

In another study, video clips of whole bodies showing either a neutral or a fear expression were employed (Grèzes et al., 2006). An enhancement in amygdala activity was found during the perception of both static and dynamic fear bodies, with increased activity in the STS and premotor cortex. Since increased responses in the STS and premotor cortex are related to increased connectivity between these regions and the amygdala, these results support the idea of a crucial role played by the amygdala in tuning the motor system to the affective meaning of sensory inputs. In addiction, these results provide evidence in favor of a relative independence between fear processing and systems for action representation.

Perception of a fear stimulus triggers a fear reaction in the observer based on direct activation of a fear motor program that is encoded in subcortical circuitry and not on imitation. Fear reactions and fear contagion following the observation of fear reactions don’t require the involvement of the cortical action circuit in which mirror neurons have a role, at least not at the basic level.

The relation between these two systems is actually still a mate of debate and more studies are needed in order to clarify this aspect.

CHAPTER 4

MODULATION OF VISUO-SPATIAL ATTENTION IN A MODIFIED LINE BISECTION TASKS BY MEANS OF EMOTIONAL CUEING IN SPATIAL NEGLECT PATIENTS AND HEALTHY SUBJECTS

4.1. Introduction

Previous studies have administered adapted line bisection tasks to spatial neglect patients, showing that the rightward bisection bias tends to decrease with unilateral left cues, such as figures or letters, while it is enhanced with unilateral right cues (Riddoch, Humphreys, 1983).

The mechanisms underlying this facilitation process are still not well clarified, although two hypotheses have been advanced: an attentional hypothesis and a perceptual hypothesis. The former assumes that a cues draws attention to the side where it is placed, thereby rendering that side more salient. As a consequence, the length of that side is overstimated and the midline is assigned toward that side (Milner et al., 1992; Smania et al., 1998; Pouget & Driver, 2000; Olk & Harvey, 2002). The latter hypothesis argues that the effects of cueing are determined by the alteration of the perceptual point of balance of the stimulus, then increasing the line’s horizontal extent (Fischer, 1994).

In light of evidence proving a role of threatening stimuli in modulating spatial attention, even under condition where, due to spatial neglect, the conscious detection of stimuli in the contralesional side is prevented, we can assert that:

a. The emotional content of stimuli can be processed in the neglected hemifield.
b. The results of the elaboration affect the focus of attention.
c. This modulation of spatial attention guides the subsequent orientation behaviour and motor output toward salient event in the left hemifield.

As described in the previous chapter, Tamietto and colleagues (2005) used emotional faces (happy and fearful) as unilateral cues in a line bisection task, administering the experimental task to a patient suffering from neglect and four control subjects which right hemisphere lesions.

In patient with neglect, differently from that observed in control subjects, left happy and angry faces were more effective than left neutral faces in reducing the rightward directional bias, with the modulation of emotional faces on line bisection confined to the left (neglected) hemispace.

The different influence of left cues in neglect patient as a function of their emotional value clearly supports the idea that the cueing effect works through biasing attention rather than by altering the perceptual point of balance (at least in the contralesional hemispace).

The emotional value of threatening stimuli has been proved to be strong for both facial and bodily expression, due to the relevant social value of these stimuli (de Gelder 2006, 2009, 2010).

From a perceptual point of view, an important difference between these two kinds of stimuli is that, while bodily expressions can be recognized from far away, the face expressions require the viewer to be nearby.

In spatial neglect syndrome, distinct portions of the space can be affected, namely the personal, peripersonal (near) and extrapersonal space. Starting from these considerations, we could assume that patient with spatial neglect mainly affecting the near space will reallocate spatial attention after the presentation of emotional stimuli represented by fearful faces in the contralateral near space; on the other side, in patients where the far space is predominantly affected by the hemi-inattention, the modulation of spatial attention will be consequent to bodily expression presented in the far extrapersonal space.

4.2 Aims

Starting from the promising results obtained by Tamietto et al. (2005; 2006), the research discussed in this work attempts to:

- Provide further empirical evidence in favour of the observation that negative emotional expressions, like fearful ones, have a higher capacity to attract attention than positive ones (such as happiness). In fact, not unique results have been obtained in the research about emotional stimuli able to summon spatial attention (Tamietto, 2005; Villeumier, 2008).
- Employ both facial and bodily expressions, where the latter kind of stimulus has been considered only recently, and to specifically verify whether facial expressions can more easily involve spatial attention if presented in a peripersonal space, bodily ones in an extrapersonal space.

- Prove that the difference in faces and bodies influence over spatial attention is related to the specific portion of space involved in spatial neglect (peripersonal or extrapersonal), according to patients behaviours in different preliminary tasks.
- Investigate, in a sample of healthy participants, the modulation of spatial attention by means of emotional face and body expressions, according to the phenomenon called “pseudo-neglect”.

4.3 Methods

4.3.1 Sample

The experimental sample was composed by patients who had unilateral right lesions due to vascular (ischemic or emorragic) accident with unilateral spatial neglect (N+) and healthy subjects.

N+ group was composed by 24 subjects, 12 male and 12 female (mean age: 67.5, s.d.: 9.48; mean education level: 7.62 years, s.d.: 4.53 years). Among them, 19 were classified into the N+P group (10 females, 9 males; patients with neglect for mainly the peripersonal space) and 5 of them into the N+E group (3 males, 2 females; patients with neglect for mainly the extrapersonal space). They were recruited at three different sites: in Bergamo, at the Riuniti Hospital and at Trescore Balneario Hospital; in Turin, at the San Camillo Hospital.

Patients were included in the N+ group if they obtained a below cut off score at the standard assessment of neglect (BIT, cut off: 129) or in at least one conventional subtest, showing the presence of perceptual neglect (line crossing, letter cancellation, star cancellation, line bisection, figure and shape copy).

Healthy participants were matched to the patient group, according to age, gender and level of education (20 subjects, 10 male and 10 female; mean age: 63, s.d.: 8.84; mean education level: 9.5 years, s.d.: 4).

The research was conducted in collaboration with the University of Turin, after approval by the Ethics Committee of The Department of Psychology of Turin and of the Department of Human Sciences of Bergamo.

All patients also had neuroimaging examination (MRI), in order to highlight the site and extension of cerebral lesion, together with campimetric investigation, for assessment of visual field size.

With regard to control subjects, the inclusion criterion was the absence of cognitive impairment (MMSE > 24) and no history of neurological or psychiatric disorder.

All participants signed informed consent for the elaboration of personal data, in accordance with Law 675/1996 (model 2003).

4.3.2 Assessment

All patients and healthy subjects underwent a screening evaluation of cognitive functions, through the Mini Mental State Examination (MMSE) (Folstein & McHugh, 1975), and a neuropsychological assessment aimed at verify the presence of neglect for the peri-personal space, by the administration of the Behavioural Inattention test (BIT) (Wilson, Cockburn & Halligan, 1987). The Ekman 60 Faces test for assessing recognition of basic facial expressions of emotion has been also employed (Ekman & Friesen, 1976). These tests are described in the next paragraphs, together with the experimental line bisection task.

4.3.2.1 The Mini Mental State Examination

The mini-mental state examination (MMSE) is a brief 30-point questionnaire test that is used to screen for cognitive impairment at a given point in time and to follow the course of cognitive changes in an individual over time and in response to a (pharmacological or cognitive-behavioural) treatment (Folstein & McHugh, 1975).

Any score greater than or equal to 25 points (out of 30) is considered effectively normal. Below this, scores can indicate severe (≤9 points), moderate (10-20 points) or mild (21-24 points) cognitive impairment. The raw score must be corrected for educational level and age.

The presence of purely physical problems can interfere with interpretation if not properly noted; for example, a patient may be physically unable to hear or read instructions properly or may have a motor deficit that affects writing and drawing skills.

4.3.2.2 The Behavioural Inattention Test

The Behavioural Inattention Test (BIT, Wilson, Cockburn, Halligan, 1987) is a standardized assessment for unilateral visual neglect, useful in order to provide detailed profiles of each patient, with regard to both perceptual and behavioural aspects in the peripersonal space.

The BIT is composed of 6 conventional sub-tests, developed as paper and pencil tasks, and 9 behavioural sub-tests, reflecting daily life activities.

The conventional sub-tests include many traditionally used measure of visual neglect: line cancellation, letter cancellation, star cancellation, figure and object copy, line bisection, and drawing by memory.

Scores from the BIT subtests can be used to calculate an aggregate score for the six tests. Points are given for correct performances: higher scores indicate better performances. A score at or below 129 on the 6 conventional tests is used to indicate that a patient has an attentional problem which requires further investigations on the behavioural tests.

An alternative way of scoring, which has the advantage of providing specific information about the potential different types of neglect involved, is to note the number of tests (using the individual tests cut-off) on which inattention is present. A patient scoring above 129 but failing at or below the cut-off score for one or more of the individual conventional subtests should also be assessed with the behavioural subtests.

Results from the latter would then provide a clearer picture of spatial neglect manifests in everyday life.

Subtests	**Acceptable range**	**Cut-off scores**
Line crossing	35-36	34
Letter cancellation	33-40	32
Star cancellation	52-54	51
Figure and shape copy	4	3
Line bisection	8-9	7
Representational drawing	3	2
Total		129

Fig. 4.1 Cut-off score for conventional subtests (BIT)

The nine behavioural sub-tests consist of: picture scanning, telephone dialling, menu reading, article reading, tell/set time, coin sorting, address and sentence, map navigation and card sorting.

Subtests	**Acceptable range**	**Cut-off scores**
Picture scanning	6-9	5
Telephone dialling	8-9	7
Menu reading	9	8
Article reading	9	8
Tell/set time	9	8
Coin sorting	9	8
Address and sentence	8-9	7
Map navigation	9	8
Card sorting	9	8
Total		129

Fig. 4.2 Cut-off score for behavioural subtests (BIT)

4.3.2.3 The Ekman 60 faces test

The Ekman 60 Faces Test uses a range of photographs from the Ekman and Friesen series of Pictures of Facial Affect (Ekman & Friesen, 1976), which has been the most widely used and validated series of photographs in facial expression research. From this series, the faces of 10 actors (6 female, 4 male) were chosen, each displaying six basic emotions (happiness, sadness, disgust, fear, surprise and anger). The Ekman 60 Faces Test can be used to assess recognition of facial expressions of basic emotions. Cards are presented one at a time to the subject, which has to name the emotion depicted on the photographs.

The maximum test score indicating the best performance is 60 for all six emotions and 10 for each basic emotion. The cut-off score has been established at 42 correct answers. A partial cut-off is also present for each emotion to be recognized.

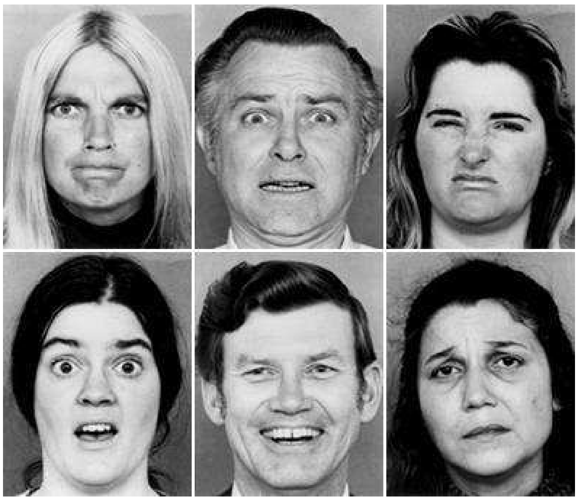


Fig. 4.3 Some examples of photographs from the Ekman 60 Faces Test

4.3.2.4 Experimental line bisection task

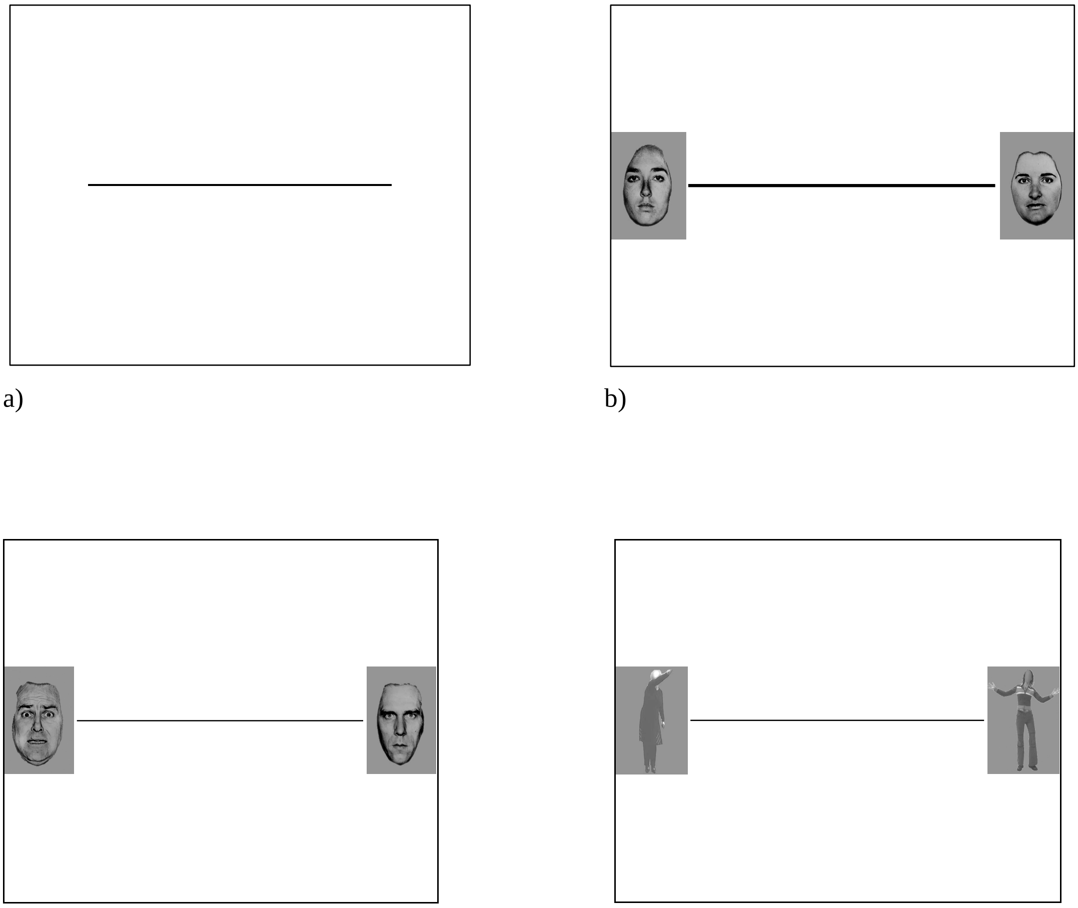
In the experimental line bisection task subjects were required to indicate with a laser pointer the midpoint of horizontal lines projected onto a screen. The midpoint of each line was aligned with the patient's mid-sagittal plane.

Each line was placed horizontally and centrally on the projector screen. Black-and-white 60 × 40 mm photographs of actors taken from Ekman's series (Ekman and Friesen, 1976) and gray-scale whole-body photographs with either a neutral, happy, or fearful expression served as cues and could be present at the right or left end of the line, or absent. The neutral faces provided an appropriate and extremely conservative control condition because, like emotional faces, they belong to the same stimulus category, have the same personal identity (as the same actors presented with a neutral expression were also shown with an emotional expression), and share the same dimensions, elementary components and global configuration.

The 44 trials were presented in a randomized fashion, consisting of totally four for each of the following conditions:

a. Simple line (simple bisection condition)
b. Neutral Face on both left and right side (face condition NN)
c. Neutral Body on both left and right side (body condition NN)
d. Left-sided Fearful Face – Right sided Neutral Face (face condition FN)
e. Left-sided Fearful Body – Right sided Neutral Body (body condition FN)

f. Left-sided Happy Face – Right sided Neutral Face (face condition HN)
g. Left-sided Happy Body – Right sided Neutral Body (body condition HN)
h. Right-sided Fearful Face – Left sided Neutral Face (face condition NF)
i. Right-sided Fearful Body – Left Sided Neutral Body (body condition NF)
j. Right-sided Happy Face – Left sided Neutral Face (face condition NH)
k. Right-sided Happy Body – Left sided Neutral Body (body condition NH)



a) b)

c) d)

Fig. 4.4 a) simple line bisection task; b) line bisection with left and right neutral faces c) line bisection with left fearful face and right neutral face d) line bisection with left neutral body and right happy body

The same task was repeated twice at different distances: the first at 60 cm distant from the subject (peri-personal space) and the second at 150 cm distant from the subject (extrapersonal space).

Lines length was 24 cm in the near space and 60 cm in the far space; these measures have been computed, in order to maintain the same angle of view in both conditions.

4.4 Procedure

4.4.1 Experimental Procedure and Task administration

The preliminary and experimental tests were administered in two different sessions within a week.

With regard to both N+ patients and control subjects, in the first session, evaluation of global cognitive level (MMSE), hemispatial neglect (BIT) and recognition of facial expressions of basic emotions was performed. In the other session, the adapted line bisection task was administered in the near and far space. Each session took about one hour to be concluded.

With regard to line bisection task, patients were not informed about the possible presence of emotional cues at the sides of the line, but they were only required to mark the midpoint of horizontal lines with the laser pointer.

Errors in line bisection for each patient and condition were measured to the nearest millimeter by an experimenter. Errors to the right of the objective midpoint were measured as positive value and those to the left a negative value.

Mean bisection errors performed in simple line bisection task presented in the near and far space were used in order to classify patients according to the presence of neglect for (mainly) the peripersonal (N+P) or extrapersonal (N+E) space.

4.4.2 Statistical Analysis description

Eight separated paired sample t-test were computed for both patient groups, comparing neutral face (face condition NN) and neutral body (body condition NN) conditions to:

- Left-sided Fearful Face (face condition FN)
- Left-sided Fearful Body (body condition FN)
- Left-sided Happy Face (face condition HN)
- Left-sided Happy Body (body condition HN)

In order to highlight the modulation of attention by means of the emotional cueing in the two patient’s group (N+P and N+E), according to the distance and the stimulus type, face or body, an index was computed, consisting of the difference between bisection errors in conditions represented by both sided neutral expressions vs fearful/happy facial and bodily expressions as left-sided cues in the near and far space (NearFaceNN – NearFaceFN/HN; Near BodyNN – NearBodyFN/HN; FarFaceNN – FarFaceFN/HN; FarBodyNN – FarBodyFN/HN).

Then, two mixed Anova were computed, with the clinical condition (N+P vs N+E) as independent variable and the indexes as dependent variables, once with fearful and once with happy expressions (within factors: distance X stimulus type). Post hoc tests (Fisher test) were then performed for the significant effects.

Control subjects were divided into two groups, according to participant's age: in the "younger" group were included participants aged from 48 to 60 years, while the "older" group was composed by participants aged from 61 to 80 years.

A paired sample t-test was computed on the mean errors in the simple bisection task performed in the near and far space, in order to investigate the presence of pseudoneglect in peripersonal or extrapersonal space. An independent sample t-test was performed on simple line bisection tasks mean errors in the two age groups.

Then, 16 paired T-test were performed, comparing neutral face (face condition NN) and Neutral body (body condition NN) vs:

d. Left-sided Fearful Face (face condition FN)
e. Left-sided Fearful Body (body condition FN)
f. Left-sided Happy Face (face condition HN)
g. Left-sided Happy Body (body condition HN)
h. Right-sided Fearful Face (face condition NF)
i. Right-sided Fearful Body (body condition NF)
j. Right-sided Happy Face (face condition NH)
k. Right-sided Happy Body (body condition NH)

This analysis was computed for both the overall sample of control participants, and on the two age groups separately.

Finally, an independent sample t-test was performed in order to compare healthy subjects group and 24 N+ patients group mean scores on the 60 faces Ekman test, assessing the explicit recognition of facial expressions of emotions.

4.5 Results

4.5.1 Patients group

N+P group showed a mean misbisection error of + 0.95 cm (s.d.:1.42) in the near space and -0.20 cm (s.d.: 0.97) in the far space; N+E patients, on the other side, showed a global rightward misbisection tendency, with a mean of + 3.17 cm (s.d.:3.87) in the near space and + 6.35 cm (s.d.: 6.08) in the far space (for details about patients performances see Appendix A, tables 1A and 2A).

Paired t-test analysis in the two groups showed the following results:

- N+P: in the near space, a significant effect of both fearful ($t = 8.86$, $p < .001$) and happy ($t = 4.01$, $p < .001$) faces was present; as for the far space, a significant influence of bodily expressions was observed, both fearful ($t = 2.87$, $p < .02$) and happy ($t = 2.7$, $p < .02$). The modulation by means of emotional stimuli was significant only for left-sided cueing, while right sided emotional cues did not turn into an increase in rightward bias during line bisection, with respect to neutral ones (see Appendix B).
- N+E: a significant reduction in bisection error was present with fearful bodily expressions presented in the far space ($t = 6.75$, $p < .001$). See Appendix C.

In the graphs below, the different modulation of line bisection errors according to the emotional cueing conditions is showed, in the N+P (Fig. 4.5) and N+E (Fig. 4.6) group.

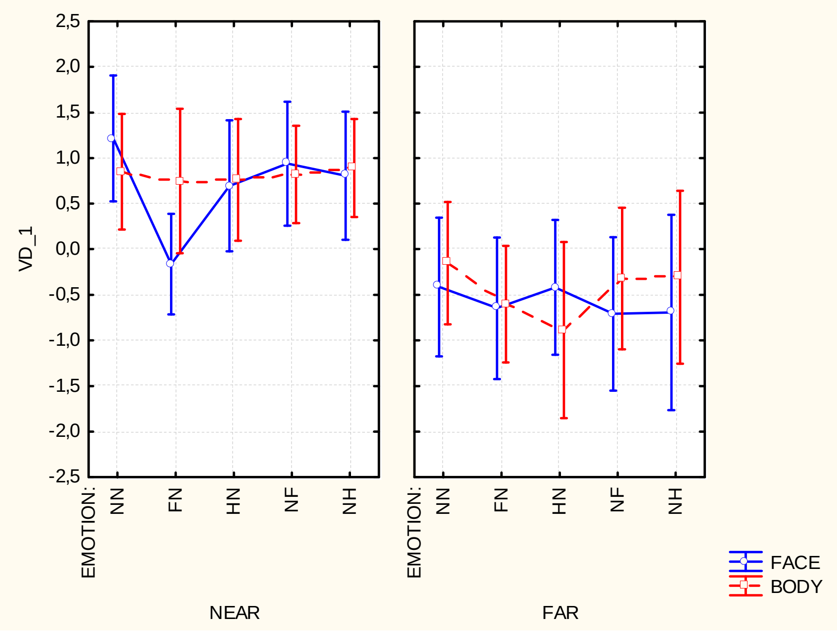


Fig. 4.5 N+ P group: effects of emotional cueing on line bisection, which are more consistent for fearful face in the near space.

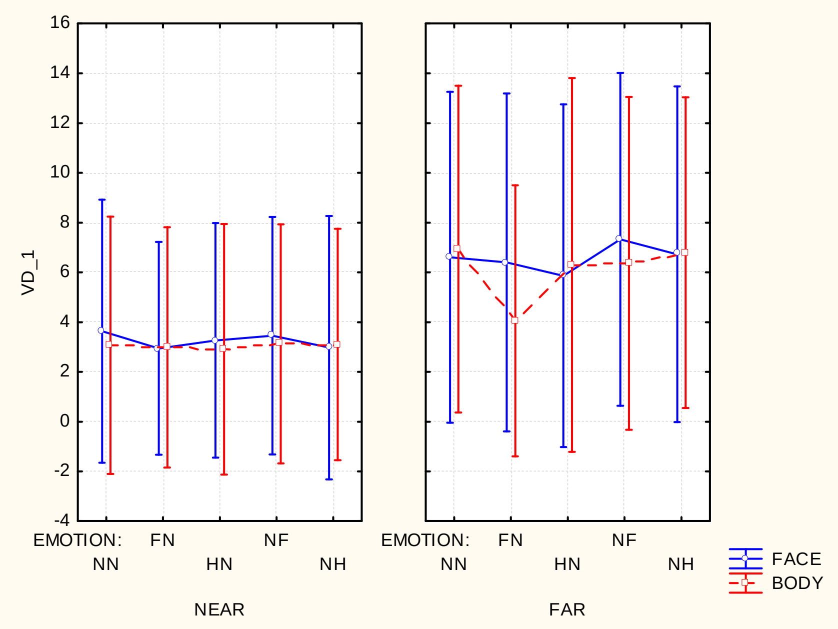


Fig.4.6 N+ E group: effects of emotional cueing on line bisection, with a significant reduction in rightward error with left-sided fearful bodily expressions in the far space.

Mixed Anova with index computed on happy expressions revealed no significant main or interactions effects (see Appendix D, Table 1D). For the index computed on fearful expressions, the following interaction effects were significant: the Distance X Group interaction (F (1,22) = 14.72, p < .001; see fig. 4.7), the Stymulus Type X Group interaction (F (1,22) = 14.28, p < .01; see fig. 4.8), the Distance X Stymulus Type Interaction (F (1,22) = 36.24, p < .00, see fig. 4.9) and the Stymulus Type X Distance X Group interaction (F (1,22) = 5.09, p < .05, see fig. 4.10). No main effects were observed (see Appendix D, Table 2D).

Post-hoc test showed that, for the Distance x Group interaction (Appendix D, Table 3D), N+P and N+E index were significantly different with regard to the far space (N+P mean: 0.34; N+E mean: 1.54, p < .000), while not for the near space (N+P mean: 0.74; N+E mean: 0.38, p = .25).

In the Stymulus Type X Group interaction (Appendix D, Table 4D), a significant difference between the two group’s indexes was found with regard to body condition (N+P mean: 0.27; N+E mean: 1.48, p <.000).

In the Distance X Stymulus type interaction (Appendix D, Table 5D), a significant difference was observed between index computed on face in the near and the far space

(Near Face mean: 1.23; Far Face mean: 0.22, p < .00) and body in the near and far space (Near Body mean: 0.09, Far Body mean: 0.95, p < .002); besides, between face and body in the near space (p < .00) and in the far space (p < .01).

Post-hoc test computed on Stymulus Type X Distance X Group interaction (Appendix D, Table 6D) showed that a significant difference was present between N+P and N+E indexes with regard to the effect of fearful body expressions in reducing the rightward error in the far space (p < .000), which was larger for the N+E group (N+P mean: 0.44; N+E mean: 2.88); the difference between the two groups for fearful face expressions index in the near space was not significant (p= .12).

Besides, a significant difference was observed, for the N+P group, between face and body expressions index in the near space (Face mean: 1,37; Body mean: 0.10, p < .000), and not in the far space; on the contrary, the same difference was significant for N+E group, only in the far space (Face mean: 0,2, Body mean: 2.88, p< .000).

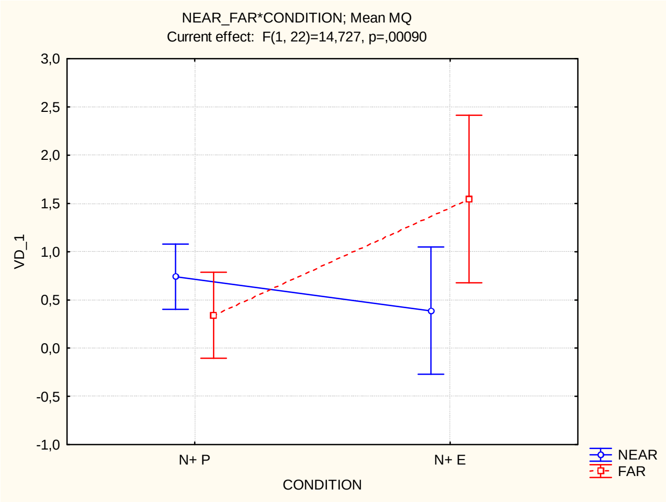


Fig. 4.7 Mixed Anova - Distance x Group Interaction

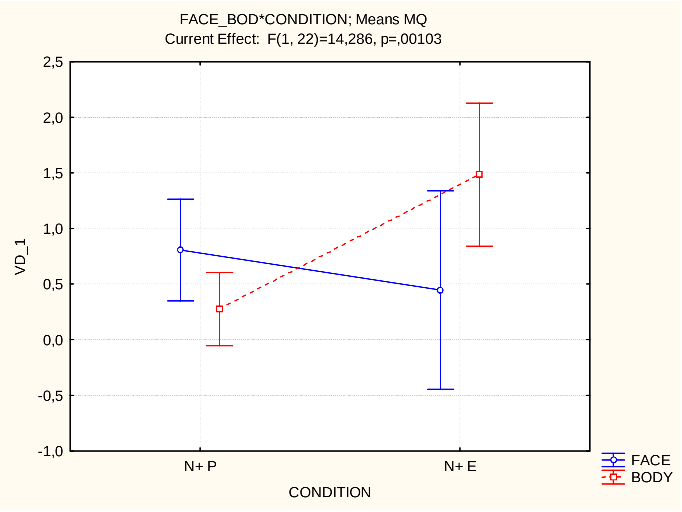


Fig. 4.8 Mixed Anova – Stymulus type x Group Interaction

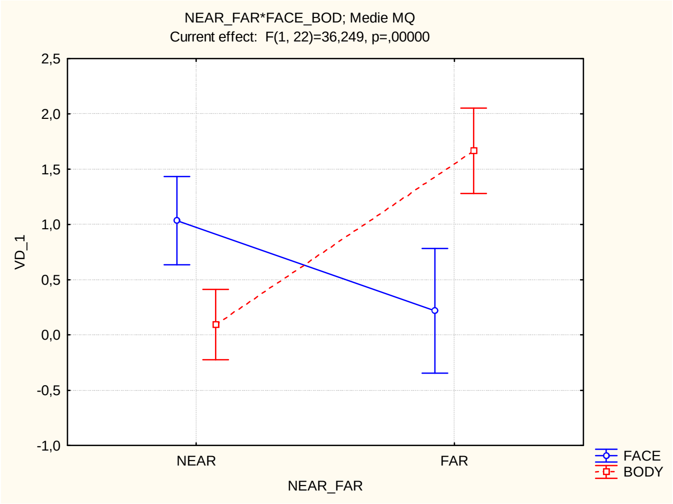


Fig. 4.9 Mixed Anova: Distance X Stymulus type Interaction

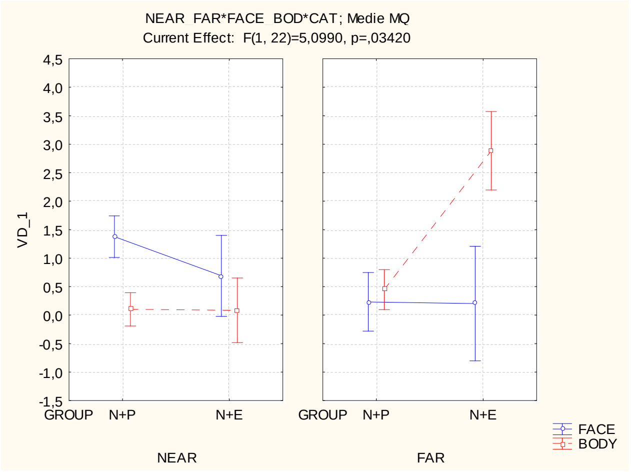


Fig.4.10 Mixed Anova: Distance X Stymulus type X Group Interaction

4.5.2 Control subjects

Healthy participants showed a mean line bisection errors of +0.05 (s.d.: +0.54) in the near space and – 0.15 (s.d.: +0.94) in the far space (Appendix A, Table 3.A). With regard to 48-60 years aged subjects, a mean bisection error of +0.02 (s.d.: +0.56) in the near space and of -0.66 (s.d.: +0.71) in the far space was observed; subjects aged from 60 to 80 showed a mean bisection error of +0.09 (s.d.: +0.54) in the near space and +0.37 (s.d.: +0.88) in the far space (Appendix A, Table 4.A).

The paired t-test on mean simple line bisection errors revealed the absence of a significant difference between performances in the near vs far space (t = 0.86, p = .39). See Appendix E, Table 1.E.

The independent sample t-test performed on the age-group as two-level independent variable showed that performances in the simple line bisection task were significantly different between younger and older subjects with regard to the far space (t = -2.895, p < .02, see Appendix E, Table 3.E), with the former showing a leftward bias (mean: -0.66), and the latter presenting an opposite rightward bias (mean: +0.37), with respect to the objective midpoint. No differences were observed with regard to the line bisection in the near space (t = -0.26, p = 0.79, see Appendix E, Table 2.E), with an almost overlapping performance in the two groups (mean of younger subjects: +0.02; mean of older subjects: +0.085).

According to the paired t-test performed on the 20 healthy subjects sample, no significant effects were found in comparing neutral conditions to emotional cueing conditions, except for the presence of a significant difference between neutral and fearful left-sided bodies in the near space (t = -2.69, p < .02); in that case, fearful bodies seems to direct spatial attention toward the opposite side, that is the right side (see Appendix F).

The same analysis, computed on the two separated age groups, still did not showed significant differences between neutral and emotional conditions.

Finally, the comparison between mean scores obtained by neglect patients and healthy subjects in the Ekman 60 faces test showed the presence of significantly higher score in healthy sample compared to N+ patients (healthy subjects mean score: 50.25, s.d.: 8.55; N+ patients mean score: 41.41, s.d.: 6.75, t = -3.78, p < .00, see Appendix G, Table 1.G).

CHAPTER 5
DISCUSSION AND CONCLUSIONS

5.1 Discussion

Our study confirms that, despite right hemisphere damage and abnormal spatial biases in attention, line bisection in neglect patients is still reliably influenced by emotional expression in faces and bodies.

In a previous study, Tamietto et al. (2005), showed that in a patient with USN left happy and angry faces were more effective than left neutral faces in reducing the rightward directional bias, with the modulation of emotional faces on line bisection confined to the left (neglected) hemispace. Supporting these results, we found that right sided emotional cues did not turn into an increase in rightward bias during line bisection, with respect to neutral ones. The different influence of the left cues in a neglect patient as a function of their emotional and attentional value clearly supports the idea that the cueing effect works through biasing attention rather than by altering the perceptual point of balance (at least in the contralesional hemispace). This hypothesis, already challenged by Tamietto et al. (2005), now seems even more unlikely. Perhaps, other mechanisms operate in the ipsilesional side, with the attentional modulation arising from emotional stimuli probably competing with perceptual and top-down processes.

With regard to the possible mechanisms underlying these findings, neuroimaging studies in humans have shown that amygdala activity can be elicited by fear-related stimuli without explicit attention to these stimuli (when task irrelevant), or even without actual awareness of the faces, when masked in normal subjects or in neurological patients with an impairment in spatial attention (parietal neglect) or in visual perception (cortical blindness) due to a cerebral damage.

The activation of limbic structures, in particular the amygdala, by means of emotional stimuli, has been proved to modulate the early visual processing and peripheral stimulus detection across the visual field (Vuilleumier 2001; 2004).

In patients with USN, the amygdala might be activated by information from the contralesional hemispace through direct pathways from the thalamus, or via ventral occipito-temporal pathway (de Gelder et al., 1999; Morris et al., 1999; Morris et al., 2001). Besides, due to its spread connections with cortical and subcortical regions, the amygdala might exert its modulatory role by direct projections to visual areas (Vuilleumier et al., 2004), via reciprocal connections to the anterior attentional network in the dorsolateral prefrontal cortex (Pessoa et al., 2002), or through complex interactions with other medial temporal structures (e.g., the hippocampus) and prefrontal areas involved in memory functions (McGaugh, 2000; Roozendaal et al., 2004).

In patients with neglect, where spatial attention mechanisms are impaired due to parietal damage, intact visual pathways into the temporal lobe and limbic areas might still mediate mechanisms of emotional attention allowing privileged detection of threat related stimuli.

As for the emotional modulation arising from bodily facial expressions in the far space, we refer to the 'two-systems' model of emotion–behavior connectivity, postulated by de Gelder for the elaboration of EBL (2006). In this model, a subcortical pathway, composed of the superior colliculus, pulvinar, striatum (putamen and caudate) and basolateral amygdala, sustains the rapid automatic perception of EBL, even in absence of detailed stimulus processing. This adaptive route, not requiring the operation of fronto-parietal regions, could have been recruited in USN patients for the detection of emotional bodily expressions, providing an attentional enhancement toward those stimuli.

According to this hypothesis, the amygdala, together with other limbic structures (cingulate and orbitofrontal cortex) involved in the unconscious detection of emotional and meaningful stimuli were undamaged in our sample of patients.

On the contrary, the overt recognition of facial expressions, as measured through the 60 faces Ekman test, resulted to be globally impaired in patients; these results support the presence of a dissociation between conscious and unconscious recognition of facial expression of emotion, being the latter related to a "short route", which does not require the involvement of detailed information from the sensory cortex.

An important aim of our study was to investigate the presence of a separated effect for facial and bodily expressions when presented in the near and far space. According to De Gelder "*…it seems likely that faces are used for fine-grained analysis of communication intention and possibly also convey a broader range of subtle emotions in a setting of close-by person to person. In contrast …bodily expressions allow for appraisal of action intention and emotions over larger distances…A major consequence of these considerations is that bodily expressions can be recognized from far away while the face expressions require the viewer to be nearby…*" (de Gelder et al., 2010).

Our study proved the presence of a different modulation of attention arising from expressive faces and bodies in the near and far space, with a more significant effect for face presented in the peripersonal space and for bodies in the extrapersonal space, and no effects for faces in the far spaces and for bodies in the near space.

With regard to patients classification according to main peripersonal or extrapersonal impairment of spatial attention, performances observed in the line bisection task in patients with a more evident spatial attention deficit for the far space have been critically enhanced by fearful bodies at an extra-personal distance, whilst patients with a main impairment of spatial attention for the near space seem to benefit from both fearful and happy expressions constituted by facial expressions presented at a near (peri-personal) distance and bodily expressions at a far (extra-personal) distance.

Perhaps, some biases in patient categorization and in the selection of assessment measures can have influenced the observed results. First, a strongly selective impairment for the far space is not present in the N+E group, with patients showing a consistent, even if less significant, rightward tendency also in the near space. Second, patients were assigned to the N+E and N+P groups according to performance on the simple line bisection test, even if performances on other visuo-spatial tasks could highlight the presence of an impairment also for extrapersonal space in some of these patients.

Interestingly, our results indicate that emotional influences on attentional processes is mediated not only by fearful expressions, but also happy ones, suggesting that facilitatory effects are not restricted to negative or threat-related stimuli. Such modulation of spatial attention by means of happy expressions has been found only with regard to N+P group, whilst in N+E subjects a significant reduction in bisection error was observed only with fearful bodily expressions presented in the far space.

The majority of studies performed with USN patients have found a role of threatening or negative stimuli in modulating spatial attention. However, some researches has provided contrasting findings, by giving empirical support to a modulation of spatial attention by means of both happy, angry and fearful facial expressions (see for example Villeumier et al. 2001, 2008; Tamietto et al., 2005).

Previous research proved that positive and reward-related stimuli can modulate visual attention, and are associated with an increased activation in the amygdala and in the visual cortex (Pessoa, 2002; Villeumier, 2007).

Besides, some Authors (Williams, Morris et al., 2004), performing a neuroimaging study under conditions of binocular suppression, proved that the amygdala has a limited capacity to differentiate between specific facial expressions when it must rely on information received via a subcortical route, so that it responds non selectively to both threatening and nonthreatening facial expressions. On the contrary, they found that amygdala activation increased in response to fearful versus neutral faces regardless of whether faces were perceived consciously or unconsciously.

By extending these considerations to our study, we could argue that our N+P patients showed a significant modulation of attention by means of both happy and fearful facial expressions, due to the activation of a subcortical route for the unconscious perception of cueing stimuli in the left space.

With regard to bodily expressions, studies by De Gelder et al. (2009, 2010) proved that in patients with reduced consciousness of visual stimuli, faces and bodies induce highly similar response; these types of stimuli seem to share a common representation, probably in subcortical structures, such as the superior colliculus and amygdala, responsible for coarse evaluation of the affective relevance of visual stimuli.

Probably, the recruitment of a larger sample of patients with a selective spatial neglect for extrapersonal space could help to clarify why no effect of happy facial expressions has been found in our sample of N+E patients.

In control subject results, some considerations can be drawn from line bisection task and attentional modulation by means of emotional facial and bodily expressions.

First, the phenomenon called “pseudoneglect”, arising from the observation that neurologically normal subjects systematically misbisect space during visual line-bisection, generally erring to the left of veridical center when bisecting horizontal line, has been observed in younger participants.

This leftward tendency in normal subjects has been hypothesized to result from a parietal asymmetry in attentional control, which gives rise to some degree of hyper-attentiveness to the left visual field (see Jewell & McCourt, 2000; McCourt, 2001; McCourt & Jewell, 1999; McCourt et al., 2000). Functional imaging (fMRI) studies have confirmed a central role for right parietal cortices in performance of line-bisection tasks (Weiss et al., 2000; Fink et al., 2000a, 2000b, 2001, 2002; Galati et al., 2000).

Neglect and pseudoneglect has been discussed as related phenomenons, both underlying on an attentional asymmetry due to right hemisphere dominance. This assumption seems to be confirmed by recent evidences, showing a similar susceptibility to a variety of modulating variables, such as age, hand used to perform bisection, the use of lateralized cues (for a review, see Jewell and McCourt, 2000). Among the influencing variables, sex is still under debate, since controversial results have been found.

According to the literature, sustaining a trend of greater rightward error with increasing age, in our study an analogue trend has been observed between younger and older than 60 years old participants. However, this trend has resulted to be significant only with regard to the far space. This last aspect appears in contrast with some studies, supporting the presence of greater leftward errors for lines presented at near distances (Barret, Crucian, and Heilman 1999; McCourt & Garlinghouse, 2000).

Since the line length has been adjusted in order to maintain the same visual angle in the near and far space, the increase in the leftward error in the far space can not be explained according to an increase in the linear line length, which has been proved to be related to a greater leftward bias during line bisection (McCourt, 2001).

Previous studies, introducing unilateral left or right cues in line bisection tasks, have shown that cueing can modulate the degree of misbisection by normal subjects. Cues employed in visual line bisection tasks typically consist of letters or geometrical objects (ad example, squares) placed at one end of the line to be bisected. Most Authors report that bisections deviate from the line midpoint in the direction of the cued end as compared to no cue control conditions (Jeannerod & Biguer, 1987; Milner et al., 1992; Nichelli, 1989; Reuter-Lorenz 1990). However, other Authors found no cue effect or, as in Berti et al. (1995), a leftward bias was found in simple line bisection task, whit a rightward bias when cues were added on right, left or even both sides of the line.

In our study, no relevant effect of emotional cueing over participant performances has been observed, with exception for an effect of fearful left-sided bodies in the near space in directing spatial attention toward the opposite side, which cannot be explained with the available literature and needs more investigation.

The results observed in healthy participants may in part be due to the large variability among subjects and the recruitment in the “younger group” of subjects aged between 45 and 60 years old, not really representative of young population. Probably, the selection of a sample composed by younger participants, such as students, where the pseudoneglect has been showed to be more consistent, could provide interesting data regarding the emotional cueing effect in presence of pseudoneglect.

5.2 Conclusions

The present research was aimed at investigating how visuo-spatial attention in a line bisection task can be modulated by means of emotional expressions. In particular, we wanted to investigate these aspects in a sample of unilateral spatial neglect (USN) patients, in order to obtain, according to previous studies, a deeper insight into the implicit detection and recognition of meaningful emotional expressions, such as fear and happyness.

In fact, recent literature in the field of emotion and cognition has proved that emotions can orient spatial attention even in presence of a neurological disease leading to a reduction in perceptual awareness, such as neglect and cortical blindness. We wanted to enlarge these results, by trying to answer to some still open questions. In particular, we wanted to clarify if a favored role is present for negative emotions, with respect to positive ones, in summoning spatial attention, since not unique results have been provided to the moment. Then, we wanted to specifically verify whether facial expressions can more easily involve spatial attention if presented in a peripersonal space, bodily ones in an extrapersonal space, according to the different perceptual characteristics of those stimuli. This aspect is suitable to be studied in spatial neglect, where a dissociation between near and far space has been found, leading to selective impaired performances for one or the other among the two space sectors. In such frame, we aimed to prove that the difference in faces and bodies influence over spatial attention is related to the specific portion of space involved in spatial neglect (peripersonal or extrapersonal).

By recruiting a sample of healthy subjects, we also intended to explore if the modulation of spatial attention by mean of emotional face and body expressions can be observed even in absence of a pathological condition affecting this function, according to the phenomenon called “pseudo-neglect”.

In order to verify our assumptions, an experimental design has been developed and implemented, in order to separately study the role played by emotions expressed by faces and bodies, according to the distance from which they are presented (“near” or “peripersonal” and “far” or “extrapersonal” space) and the content of the emotional stimuli, i.e. happy or fearful versus neutral expressions.

Our results proved that emotional faces and bodies can effectively summon spatial attention even in patients with impaired processing of visual stimuli, such as USN patients. Both fearful and happy expressions has been showed to represent meaningful and salient stimuli in visual processing with regard to N+P patients; in the N+E group, only fearful bodies were observed to modulate spatial attention. This represents only a preliminary result, since a small sample has been employed and much more subjects, at least with regard to the N+E group, are needed in order to verify these observations. However, it suggests that fear may probably exert a more powerful influence with respect to positive emotions such as happiness, in modulating attentional processes.

Besides, as expected, even if not yet demonstrated up to this point, we observed a separated effect of faces and bodies according to the distance from which they were presented. In fact, in both groups, the attentional modulation, obtained by means of emotional cueing, has showed to be selectively present only for faces in the near space and bodies in the far space.

Besides, interesting considerations can be drawn with regard to the most challenging objective of this study, i.e. to verify if faces and bodies influence over spatial attention was related to the specific portion of space involved in spatial neglect (peripersonal or extrapersonal). Even if in N+P patients has been found an additional effect of bodies presented in the far space, Anova results showed that the Face-Body difference was significant for N+P in the near space and for N+E in the far space.

It is important to highlight that the right sided emotional cues did not turn into an increase in rightward bias during line bisection, with respect to neutral ones. This is a relevant issue, not only with regard to theorical considerations, but also for pratical applications of our study results.

In fact, since a consistent reduction in rightward bisection errors have been proved to arise from left-sided emotional stimulation, a possible future application could be to rehabilitation of USN. A large number of interventions are available, employing both cognitive explicit (top-down) strategies and perceptual implicit (bottom-up) methods. The use of emotional stimulation could represent a third possibility.

Finally, some important limitations are present in this study. We mention the most important, which could be more deeply investigated in future works.

First, not all patients included in the N+P group presented a clear tendency to bisect toward right during the simple line bisection task, even if the presence of USN has been evaluated by means of the administration of the BIT and have proved to be consistent. This could have added some variability to the data obtained at the experimental tasks. Besides, patients included in the N+E group also showed the presence of USN for the near space. However, since it is known that only a small proportion of neglect patients present a really pure neglect for the extrapersonal space, this issue is not easy to be avoided, if not by narrowing the selection; to do this, we would need more time and more hospitals for patient recruitment.

Besides, the Ekman 60 faces test has been useful in order to highlight the dissociation between explicit and implicit recognition of facial expressions of emotions, providing interesting data in addition to the experimental task’s. However, since the emotional cueing employed in the line bisection task was represented by both faces and bodies, it would be interesting to develop a new version of the Ekman test, by employing expressive bodies instead of faces.

Acknowledgements

This thesis represents the last step of a long and challenging route, made of hard work, but also of nice time and precious discussions.

I would like to thank people who have made my Phd possible. First, my tutor, Prof. Maria Luisa Rusconi. She has been very patient with me; in particular she tolerated my need to engage in many different actitivies with enthusiasm and my being sometimes a little bit confused with regard to professional and life choices. At the end, I think that we have been able to bring out the positive from these aspects. Prof. Giuseppe Riva, the head of Applied Technology for Neuropsychology Laboratory, at the Istituto Auxologico Italiano, who first offered me the opportunity to do research and has an open challenge to me, in the belief that research is more interesting than clinical activity. Prof. Giuliano Geminiani and the Researcher Marco Tamietto, both employed at the University of Turin; in particular the Prof. Geminiani for having helped me with the statistical analysis, and Marco Tamietto, who developed the ingenious experimental design, which is the argument of my thesis.

Then, my colleagues at the University of Bergamo, in particular Anna Paladino, Chiara Scarabelli, and Bruna Cavaletti. Anna showed me some important human and professional virtues, with her passion for reading and teaching and her love for ethics and justice. Chiara made me understand the importance of precision and patience in the research activities and helped me a lot in collecting data. Bruna gave me evidence that it is possible to do a lot of things at once, so perfectly and professionally! Work in progress for me…And Claudia Zamin, which I've known for a short time, but enough to appreciate her. Of course, all of them also made me smile, a lot.

I would like to express my gratitude also to my family, who shared with me the efforts, the anxiety and the concerns across this period of time. In particular, my mother and father, who sometimes still ask me what exactly a Phd is, yet they feel that it is a good thing for me, at the end. My brother, Paolo, who is always proud of his sister. No matters how things go.

To my boyfriend, Riccardo, who lives quite distant from me, but he has always been close to me across this time.

To my friend Alessandra, who has in common with me the experience of the Phd Course. We shared both the hard and the pleasent side of this work, building our discussions in front of a sushi or in the middle of a beach volley game…

Finally, to all my friends from the Tuscany (Veronica, Monica, Najla, Laura, Sara), who make me feel at home every time I see them; I feel them close to me, despite the distance which separates us.

APPENDIX A – PATIENTS AND CONTROL SUBJECTS DEMOGRAPHICAL AND CLINICAL CARACHTERISTICS

Table 1.A N+P Patients demographical and clinical characteristics

ID	GEND	AGE	EDU. (YEARS)	ETHIOL	ONSET (days)	MMSE	BIT (conv.)	BISEC. (near)	BISEC. (far)	EKMAN
1	F	74	5	I	45	28	126	1,05	0,525	52
2	M	68	0	I	56	24	32	3,275	0,925	45
3	M	63	13	I	35	26	117	0,225	-0,275	41
4	F	84	13	I	69	23	51	1,55	-0,8	40
5	M	71	8	I	73	20	54	2,25	0,875	41
6	M	69	0	I	100	20	21	1,15	-0,1	42
6	M	73	5	I	38	25	118	1,65	0,1	50
8	F	74	8	I	82	24	98	0,85	-1,025	43
9	F	70	8	E	70	22	40	0,675	-0,9	44
10	F	69	2	I	178	20	128	1,9	-0,35	39
11	F	68	1	I	47	20	105	1,45	1,15	43
12	M	70	5	I	390	28	113	1,325	0,175	48
13	F	74	8	I	111	29	96	3,225	0,85	53
14	F	45	13	I	90	26	106	0,2	-0,2	40
15	M	62	5	I	114	27	118	0,575	-0,275	43
16	F	85	8	I	53	26	71	0,075	-0,6	42
17	F	57	13	E	60	27	60	0,575	-0,125	31
18	M	65	17	I	57	27	107	-3,25	-2	23
19	M	54	13	I	23	26	96	-0,625	-2,575	36

Tab. 2.A N+E Patients demographical and clinical carachteristics

ID	GEND	AGE	EDU. (YEARS)	ETHIOL	ONSET (days)	MMSE	BIT (conv.)	BISEC. (near)	BISEC. (far)	EKMAN
20	F	66	8	E + I	10 years	29	128	6,5	14,25	43
21	M	82	6	I	65	23	122	1,03	2,5	45
22	F	56	11	I	36	26	12	8,15	11,6	43
23	M	62	8	I	30	29	118	0,6	1,25	40
24	M	59	5	I	30	28	97	-0,425	2,15	29

Legend.

Gend: gender
Edu: education
Ethiology: I = ischemic; E = emorragic
Bisec. : simple line bisection performance, in the near (near) and far (far) space

Tab. 3.A Control subjects demographical and clinical carachteristics

	Descriptive Statistical				
Variable	Valid	Mean	Minimum	Maximum	St.Dev.
AGE	20,00	63,05	48,00	80,00	8,85
EDUCATION	20,00	9,50	3,00	17,00	4,08
Near-Bisemp	20,00	0,05	-1,00	1,45	0,54
Far-Bisemp	20,00	-0,15	-1,95	1,38	0,94
MMSE	20,00	28,88	26,97	30,00	1,25
EKMAN	20,00	50,25	24,00	59,00	8,56
BIT	20,00	144,65	139,00	146,00	1,66

Tab. 4.A Control subjects demographical and clinical carachteristics – group age

Descriptive Statistics									
AGE	AGE Mean	AGE N	AGE St.Dev.	EDUC Mean	EDUC N	EDUC St.Dev.	MMSE Mean	MMSE N	MMSE St.Dev.
48-60	56,00	10,00	4,32	10,90	10,00	3,38	28,72	10,00	1,24
60-80	70,10	10,00	6,01	8,10	10,00	4,41	29,03	10,00	8.017,00
All subjects	63,05	20,00	8,85	9,50	20,00	4,08	28,88	20,00	1,25

Descriptive Statistics

AGE	Near-Bis Mean	Near-Bis N	Near-Bis St.dev.	Far-Bis Mean	Far-Bis N	Far-Bis St.Dev.	BIT Mean	BIT N	BIT St.Dev.
48-60	0,02	10,00	0,56	-0,66	10,00	0,71	145,00	10,00	0,94
60-80	0,09	10,00	0,54	0,37	10,00	0,88	144,30	10,00	2,16
All subjects	0,05	20,00	0,54	-0,15	20,00	0,94	144,65	20,00	1,66

APPENDIX B – STATISTICAL ANALYSIS RESULT - PAIRED SAMPLE T-TEST IN N+P GROUP ON LINE BISECTION ERRORS WITH DIFFERENT EMOTIONAL CUEING CONDITIONS

Table 1.B NN-FN

	Paired t Test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	Std.Dv Diff	t	df	p
VFaceNN	1,216	1,431						
VFaceFN	-0,163	1,142	19	1,379	0,678	8,865	18	0,000

Table 2.B NN-HN

	Paired t Test t Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff Diff.	t	df	p
VFaceNN	1,216	1,431						
VFaceHN	0,696	1,489	19	0,520	0,564	4,019	18,00	0,001

Table 3.B NN-FN

	Paired t test Significant differences marked at level p < ,05000							
Variabile	Mean	St.Dev.	N	Diff.	Dv.Std. Diff.	t	df	p
VBodyNN	0,850	1,317						
VBodyFN	0,748	1,641	19	0,103	0,614	0,729	00	0,475

Table 4.B NN-HN

	Paired t Test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St. Dev.Diff.	t	df	p
VBodyNN	0,850	1,317						
VBodyHN	0,761	1,384	19,000	0,090	0,570	0,688	18,00	0,500

Table 5.B NN-FN

	Paired t Test t Significant differences marked at the level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff	t	df	p
LFaceNN	-0,413	1,578						
LFaceFN	-0,646	1,610	19	0,233	1,005	1,010	18,00	0,326

Table 6.B NN-HN

	Paire t Test t Significant differences marked at the level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. diff	t	df	p
LFaceNN	-0,41	1,58						
LFaceHN	-0,42	1,53	,00	0,01	1,02	0,02	00	0,98

Table 7.B NN-FN

	Paired t Test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LBodyNN	-0,151	1,392						
LBodyFN	-0,601	1,327	19	0,450	0,682	2,871	18	0,010

Table 8.B NN-HN

Variable	Paired t Test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev.Diff.	t	df	p
LBodyNN	-0,151	1,392						
LBodyHN	-0,886	2,008	19	0,735	1,182	2,710	18	0,014

APPENDIX C – STATISTICAL ANALYSIS RESULT - PAIRED SAMPLE T-TEST IN N+E GROUP ON LINE BISECTION ERRORS WITH DIFFERENT EMOTIONAL CUEING CONDITIONS

Table 1.C NN-FN

Variable	Paired sample t Test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev Diff.	t	gl	p
VFaceNN	3,635	4,257						
VFaceFN	2,945	3,445	5	0,690	1,081	1,427	4	0,227

Table 2.C NN-HN

Variable	Paired sample t Test t Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
VFaceNN	3,635	4,257						
VFaceHN	3,265	3,798	5	0,370	0,868	0,953	4	0,394

Table 3.C NN-FN

Variable	Paired sample t Test t Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
VBodyNN	3,075	4,163945						
VBodyFN	2,990	3,889794	5	0,085	0,594	0,320	4	0,765

Table 4.C NN-HN

Variable	Paired sample t Test t Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
VBodyNN	3,075	4,164						
VBodyHN	2,910	4,053	5	0,165	0,362	1,020	4	0,365

Table 5.C NN-FN

Variable	Paired sample t Test t Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
LFaceNN	6,605	5,355						
LFaceFN	6,400	5,470	5	0,205	1,385	0,331	4	0,757

Table 6.C NN-HN

Variable	Paired sample t Test Significant differences marked at level p < ,05000							
	mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
LFaceNN	6,605	5,355						
LFaceHN	5,865	5,545	5	0,740	2,775	0,596	4	0,583

Table 7.C NN-FN

Variable	Paired sample t Test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
LBodyNN	6,940	5,287						
LBodyFN	4,055	4,387	5	2,885	0,955	6,758	4	0,002

Table 8.C NN HN

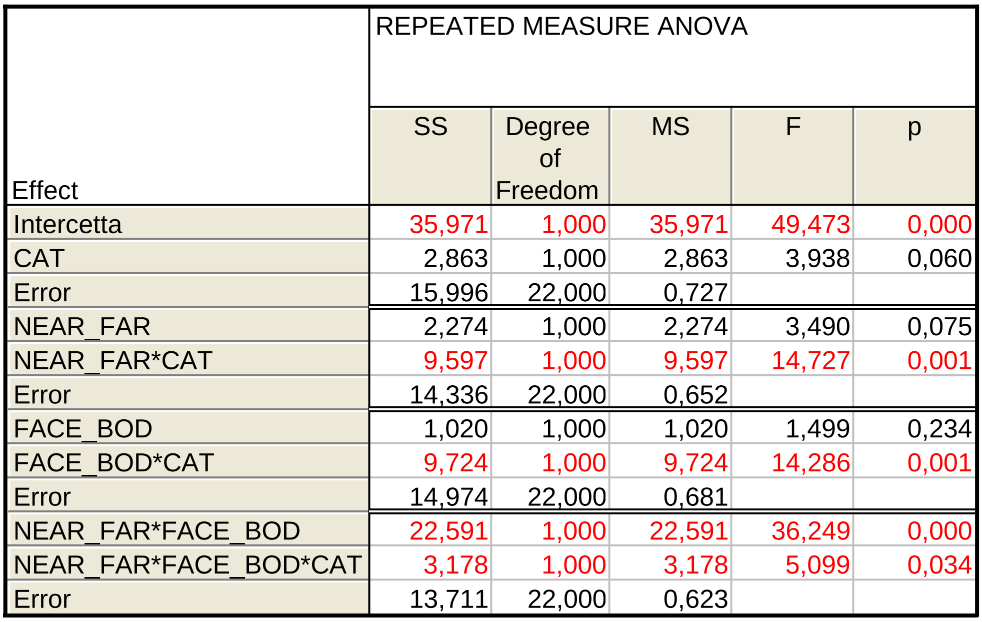
Variable	Paired sample t Test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
LBodyNN	6,940	5,287						
LBodyHN	6,295	6,052	5	0,645	1,767	0,816	4	0,460

APPENDIX D – MIXED ANOVA RESULTS IN PATIENT'S GROUPS ON INDEX OF EMOTIONAL MODULATION OF ATTENTION

Table 1.D Mixed Anova for emotion = happy

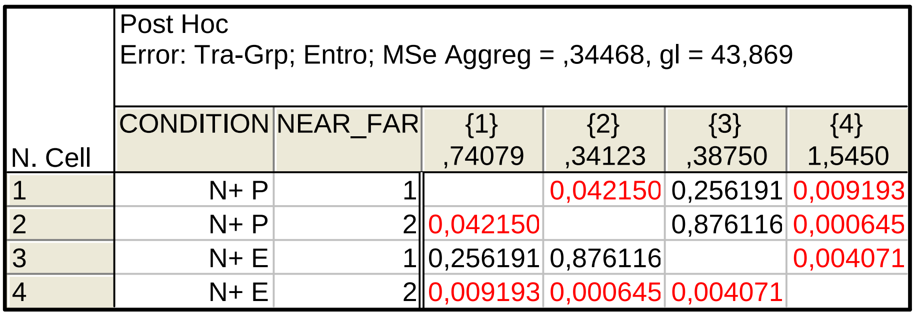
Effect	REPEATED MEASURE ANOVA				
	SS	Degree of Freedom	MS	F	p
Intercetta	10,581	1,00	10,581	5,259	0,032
CAT	0,322	1,00	0,322	0,160	0,693
Error	44,265	22,00	2,012		
NEAR_FAR	0,951	1,00	0,951	0,745	0,397
NEAR_FAR*CAT	0,512	1,00	0,512	0,401	0,533
Error	28,083	22,00	1,277		
FACE_BOD	0,000	1,00	0,000	0,000	1,000
FACE_BOD*CAT	0,356	1,00	0,356	0,550	0,466
Error	14,230	22,00	0,647		
NEAR_FAR*FACE_BOD	1,595	1,00	1,595	2,224	0,150
NEAR_FAR*FACE_BOD*CAT	1,090	1,00	1,090	1,520	0,231
Error	15,774	22,00	0,717		

Table 2.D Mixed Anova for emotion = Fear



	REPEATED MEASURE ANOVA				
Effect	SS	Degree of Freedom	MS	F	p
Intercetta	35,971	1,000	35,971	49,473	0,000
CAT	2,863	1,000	2,863	3,938	0,060
Error	15,996	22,000	0,727		
NEAR_FAR	2,274	1,000	2,274	3,490	0,075
NEAR_FAR*CAT	9,597	1,000	9,597	14,727	0,001
Error	14,336	22,000	0,652		
FACE_BOD	1,020	1,000	1,020	1,499	0,234
FACE_BOD*CAT	9,724	1,000	9,724	14,286	0,001
Error	14,974	22,000	0,681		
NEAR_FAR*FACE_BOD	22,591	1,000	22,591	36,249	0,000
NEAR_FAR*FACE_BOD*CAT	3,178	1,000	3,178	5,099	0,034
Error	13,711	22,000	0,623		

Table 3.D Post-hoc test (Fisher) for mixed Anova, emotion = Fear**,** Condition x Distance interaction effects



	Post Hoc Error: Tra-Grp; Entro; MSe Aggreg = ,34468, gl = 43,869					
N. Cell	CONDITION	NEAR_FAR	{1} ,74079	{2} ,34123	{3} ,38750	{4} 1,5450
1	N+ P	1		0,042150	0,256191	0,009193
2	N+ P	2	0,042150		0,876116	0,000645
3	N+ E	1	0,256191	0,876116		0,004071
4	N+ E	2	0,009193	0,000645	0,004071	

Table 4.D Post-hoc test (Fisher) for mixed Anova, emotion = Fear**,** Condition x Stymulus Type interaction

N. Cell	Post Hoc test Error: Tra-Grp; Entro; MSe Aggreg = ,35192, gl = 43,952					
	CONDITION	FACE_BOD	{1} ,80592	{2} ,27610	{3} ,44750	{4} 1,4850
1	N+ P	1		0,010451	0,249551	0,027678
2	N+ P	2	0,010451		0,568327	0,000619
3	N+ E	1	0,249551	0,568327		0,010154
4	N+ E	2	0,027678	0,000619	0,010154	

Table 5.D Post-hoc test (Fisher) for mixed Anova, emotion = Fear**,** Distance X Stymulus Type interaction

N. Cell	Post Hoc test Errore:MSe Entro-sg= ,62323, gl = 22,000					
	NEAR_FAR	FACE_BOD	{1} 1,2354	{2} ,09896	{3} ,22708	{4} ,95694
1	1	1		0,000054	0,000214	0,234664
2	1	2	0,000054		0,579656	0,001068
3	2	1	0,000214	0,579656		0,004107
4	2	2	0,234664	0,001068	0,004107	

Table 6.D Post-hoc test (Fisher) for mixed Anova, emotion = Fear**,** Condition x Distance x Stymulus Type interaction

	Test Post Hoc Errore: Tra-Grp; Entro; MSe Aggreg = ,67515, gl = 43,741										
	CAT	NEAR_FAR	FACE_BOD	{1} 1,3789	{2} ,10263	{3} ,23289	{4} ,44956	{5} ,69000	{6} ,08500	{7} ,20500	{8} 2,8850
1	1	1	1		0,000	0,000	0,001	0,122	0,003	0,007	0,001
2	1	1	2	0,000		0,616	0,189	0,162	0,968	0,805	0,000
3	1	2	1	0,000	0,616		0,407	0,274	0,722	0,949	0,000
4	1	2	2	0,001	0,189	0,407		0,563	0,382	0,557	0,000
5	2	1	1	0,122	0,162	0,274	0,563		0,238	0,342	0,000
6	2	1	2	0,003	0,968	0,722	0,382	0,238		0,812	0,000
7	2	2	1	0,007	0,805	0,949	0,557	0,342	0,812		0,000
8	2	2	2	0,001	0,000	0,000	0,000	0,000	0,000	0,000	

APPENDIX E: CONTROL SUBJECTS T-TEST ON SIMPLE LINE BISECTION ERRORS

Table 1.E Paired sample t-test on simple line bisection in the near and far space

	Paired sample T test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	gl	p
V-Bisemp	0,053	0,536						
LBisemp	-0,145	0,937	20	0,197500	1,016	0,869	19	0,396

Table 2.E Indipendent sample t-test on simple line bisection between the two age groups in the near space

	Test t; Group: GROUP_AGE Group1: 1 Group2: 2								
Variable	Mean 1	Mean 2	t value	df	p	N Validi 1	N Validi 2	St.Dev 1	St.Dev 2
V-Bisemp	0,020	0,085	-0,264	18	0,795	10	10	0,562	0,538

Table 3.E Indipendent sample t-test on simple line bisection between the two age groups in the far space

	Test t; Group: GROUP_AGE Group1: 1 Group2: 2								
Variable	Mean 1	Media 2	t value	df	p	N Validi 1	N Validi 2	St.Dev. 1	St.Dev. 2
LBisemp	-0,660	0,370	-2,895	18	0,010	10	10	0,707	0,876

APPENDIX F: CONTROL SUBJECTS PAIRED SAMPLE T-TEST ON LINE BISECTION ERRORS WITH DIFFERENT EMOTIONAL CUEING CONDITIONS

Table 1.F NN-FN

	Test t Paired Sample t test Significan differences marked at p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
VFaceNN	-0,015	0,412						
VFaceFN	0,006	0,462	20	-0,021250	0,231	-0,411858	9,00	0,6

Table 2.F NN-HN

	Paired sample t Test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
VFaceNN	-0,015	0,412						
VFaceHN	-0,025	0,547	20	0,010	0,209	0,214	19	0,833

Table 3.F NN-NF

	Paired sample t Test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
VFaceNN	-0,015	0,412						
VFaceNF	-0,108	0,503	20	0,093	0,274	1,508	19	0,148

Table 4.F NN-NH

	Paired sample t test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
VFaceNN	-0,015	0,412						
VFaceNH	-0,019	0,452	20	0,004	0,242	0,069	19	0,946

Table 5.F NN-FN

	Paired sample t test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
VBodyNN	-0,123	0,525						
VBodyFN	0,072	0,453	20	-0,195	0,324	-2,692	19	0,014

Table 6.F NN-HN

	Paired sample t test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
VBodyNN	-0,123	0,525						
VBodyHN	-0,033	0,423	20	-0,090	0,233	-1,726	19	0,101

Table 7.F NN-NF

	paired sample t test Significant differences marked at levelp < ,05000							
Variable	Mean	St.Dev.	N	Diff.	Dv.Std. Diff.	t	df	p
VBodyNN	-0,123	0,525						
VBodyNF	-0,124	0,535	20	0,001	0,257	0,021713	19	0,983

Table 8.F NN-NH

	paired sample t test Significant differences marked at level p < ,05000							
Variable	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
VBodyNN	-0,123	0,525						
VBodyNH	-0,033	0,446	20	-0,090	0,256	-1,57362	19	0,132

Table 9.F NN-FN

Variabile	Test t per Campioni Dipendenti Diff. marcate significative al livello p < ,05000							
	Media	Dv.Std.	N	Diff.	Dv.Std. Diff.	t	gl	p
LFaceNN	-0,302500	0,913816						
LFaceFN	-0,225000	0,868491	20	-0,077500	0,381125	-0,909387	19	0,374538

Table 10.F NN-HN

Variabile	Paired sample t test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LFaceNN	-0,303	0,914						
LFaceHN	-0,077	0,968	20	-0,225	0,568	-1,77061	19	0,093

Table 11.F NN-NF

Variable	Paired sample t test Significant differences marked at level p < ,05000							
	mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LFaceNN	-0,303	0,914						
LFaceNF	-0,133	0,906	20	-0,170	0,599	-1,26843	19	0,220

Table 12.F NN-NH

Variable	Paired sample t test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LFaceNN	-0,303	0,914						
LfaceNH	-0,284	1,158	20	-0,019	0,526	-0,159	19	0,875

Table 13.F NN-FN

Variable	Paired sample t test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LBodyNN	-0,199	0,955						
LBodyFN	-0,314	0,903	20	0,115	0,554	0,927807	19	0,365

Table 14.F NN-HN

Variable	Paired sample t test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LBodyNN	-0,199	0,955						
LBodyHN	-0,390	0,976	20	0,191	0,576	1,484995	19	0,154

Table 15.F NN-NF

Variable	Paired sample t test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LBodyNN	-0,199	0,955						
LBodyNF	-0,106	1,120	20	-0,093	0,604	-0,685142	19	0,502

Table 16.F NN-NH

Variabile	Paired sample t Test Significant differences marked at level p < ,05000							
	Mean	St.Dev.	N	Diff.	St.Dev. Diff.	t	df	p
LBodyNN	-0,199	0,955						
LBodyNH	-0,299	0,803	20	0,100	0,563	0,794	19	0,437

APPENDIX G: INDIPENDENT SAMPLE T TEST ON EKMAN'S SCORES (BETWEEN PATIENTS AND CONTROL SUBJECTS)

Table 1.G Independent sample t-test on 60 Faces Ekman test

	Indipendent sample t Test Group1: N+ Group2: control subjects								
Variable	Mean N+	Mean control	t value	df	p	N Valid N+	N Valid ctr	St.Dev. N+	St.Dev. control
EKMAN	41,500	50,250	-3,789	42,00	0,000	24,000	20,000	6,763	8,559

References

1. Albert, M.L. (1973). A simple test of visual neglect. *Neurology,* 23, 658-64.
2. Anolli L. (2002). *Le emozioni*. Edizioni Unicopli, Milano.
3. Anolli, L. & Ciceri, R**.** (1992). *La voce delle emozioni*. Milano: Franco Angeli.
4. Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, 12(2), 169-177.
5. Armony, J.L., Dolan, R.J. (2002). Modulation of spatial attention by fear conditioned stimuli: an event-related fMRI study. *Neuropsychologia*, 40, 817–826.
6. Bartolomeo, P., & Chokron, S. (2002). Can we change our vantage point to explore imaginal neglect? (Commentary on Pylyshyn: Mental imagery: In search of a theory). *Behavioral and Brain Sciences*, 25(2), 184-185.
7. Bear M. F., Connors B. W., Paradiso M. A. (1999). *Neuroscienze. Esplorando il cervello.* Masson Editore, II edizione.
8. Berti, A., Smania, N., & Allport, A. (2001). Coding of far and near space in neglect patients. *Neuroimage*, 14, S98–S102.
9. Berti, A., & Rizzolatti, G. (1992). Visual processing without awareness: Evidence from unilateral neglect, in *Journal of cognitive neuroscience,* 4, 345-351.
10. Berti, A., & Frassinetti, F. (2000). When far becomes near: Remapping of space by tool use. *Journal of Cognitive Neuroscience*, 12, 415–420.
11. Bisiach, E. (1993). Mental representation in unilateral neglect and related disorders. *Quarterly Journal of Experimental Psychology*, 46, 435-461.
12. Bisiach, E. & Rusconi, M.L. (1990). Breakdown of perceptual awarness in unilateral neglect. *Cortex*, 26, 643-49.
13. Bisiach, E. & Vallar, G. (1988). Hemineglect in humans. In Bollar, F. & Graffman, J.; *Handbook of neuropsychology*. Amsterdam, Elsevier.
14. Bisiach, E., & Geminiani, G. (1991). Anosognosia related to hemiplegia and hemianopia, in Awareness of deficit after brain injury, a cura di. Prigatano, P.G. & Schacter, D.L., Oxford, Oxford University Press.
15. Bisiach, E. & Luzzatti, C. (1978). Unilateral neglect of rappresentational space. *Cortex*, 14, 129-133.
16. Bisiach, E. (1996). Negligenza spaziale unilaterale ed altri disordini unilaterali di rappresentazione. In: G. Denes, L. Pizzamiglio *Normalità e patologia dei processi cognitivi*. Zanichelli, 639-66.
17. Bisiach, E., Perani, D., Vallar G., et al. (1986a). Unilateral neglect: personal and extrapersonal. *Neuropsychologia*, 24, 759-767.
18. Bisiach, E., Vallar, G., Perani, et al. (1986b). Unawareness of disease following lesions of the right hemisphere: anosognosia for hemiplegia and anosognosia for hemianopia. *Neuropsychologia*, 24, 471-482.
19. Bowers, D., & Heilman, K.M. (1980). Pseudoneglect: effects of hemispace on a tactile line bisection task. *Neuropsychologia*, 18, 491–498.

20. Bradley, B.P., Mogg, K., Millar, N., et al. (1997). Attentional biases for emotional faces. *Cogn Emot,* 11, 25–42.
21. Broadbent, D.E. (1958). *Perception and Communication.* London: Pergamon.
22. Carrasco, M., Penpeci-Talgar, C., & Eckstein, M. (2000). Spatial covert attention increases contrast sensitivity across the CSF: support for signal enhancement. *Vision Res,* 40, 1203– 1215.
23. Compton, R. J. (2003). The interface between emotion and attention: a review of evidence from psychology and neuroscience. *Behavioral and Cognitive Neuroscience Reviews*, 2(2), 115-129.
24. Corbetta, M., Miezin, F.M., & Shulman, G.L. (1991b). Selective Attention Modulates Extrastriate Visual Regions in Humans during Visual Feature Discrimination and Recognition. In: *Exploring brain functional anatomy with positron emission tomography.* Wiley, Chichester (Ciba Foundation 163), 165-180.
25. Corbetta, M., & Shulman, G.L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience,* 3, 201-215.
26. Cutting, J. (1978). Study of anosognosia. *J. Neurol. Neurosurg Psychiatry,* 41, 548-555.
27. D'urso, V. & Trentin, R. (1988). *Psicologia delle emozioni*. Bologna: Il Mulino.
28. Damasio A. G. (2003). *Alla ricerca di Spinoza*. Adelphi, Milano.
29. Damasio A. G. (2000). *Emozioni e coscienza*. Adelphi, Milano.
30. Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex, in *Philosophical Transactions of the Royal Society of London, Biological Sciences*, 351, 1413-1420.
31. de Gelder, B. (2006). Towards the neurobiology of emotional body language. *Nature Reviews Neuroscience*, 7(3), 242-249.
32. de Gelder, B. (2009). Why bodies? Twelve reasons for including bodily expressions in
33. affective neuroscience. *Proc. R. Soc. Lond. B Biol. Sci.,* 364 (1535), 3475–3484.
34. de Gelder, B., Frissen, I., Barton, J., et al. (2003). A modulatory role for facial expressions in prosopagnosia. *Proc. Natl. Acad. Sci.* U.S.A.
35. de Gelder, B., & Hadjikhani, N. (2006). Non-conscious recognition of emotional body language. *Neuroreport,* 17, 583–586.
36. de Gelder, B., Van de Stock, J., Meeren H.K.M., et al. (2010). Standing up for the body. Recent process in uncovering the networks involved in the perception of bodies and bodily expressions. *Neuroscience and Biobehavioral reviews,* 34(4), 513-527.
37. Denes G., & Pizzamiglio L., (A cura di) (1996). *Manuale di neuropsicologia*. Bologna, Zanichelli.
38. Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, 18, 183–222.
39. De Renzi, E. (1982). *Disorders of space exploration and cognition*, London, Wiley.
40. Dimberg, U., & Ohman, A. (1996). Behold the wrath: Psychophysiological responses to facial stimuli. *Motivation and Emotion*, 20, 149–182.

41. Downer, J. L. (1961). Changes in visual agnostic functions and emotional behaviour following unilateral temporal pole damage in the “split-brain” monkey. *Nature,* 191, 50-51.
42. Driver, J., & Vuilleumier, P. (2001). Perceptual Awareness and its Loss in Unilateral Neglect and Extinction. *Cognition,* 79 (1), 39-88.
43. Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General*, 113, 501-517.
44. Eason, R., Harter, M., & White, C. (1969). Effects of attention and arousal on visually evoked cortical potentials and reaction times in man. *Physiol. Behav*., 4, 283-289.
45. Eastwood, J. D., Smilek, D., & Merikle, P. M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Percept Psychophys,* 63(6), 1004-13.
46. Eastwood, J.D., & Smilek, D. (2005). Functional consequences of perceiving facial expressions of emotion without awareness. *Consciousness and Cognition,* 14 (3), 565-584.
47. Ekman, P, & Friesen, W. (1976). *Pictures of facial affect*. Palo Alto, CA: Consulting Psychologists Press.
48. Ekman, P., & Friesen, W.V. (1969). The repertoire of nonverbal behavior: Categories, origins, usage, and coding. *Semiotica*, 1, 49- 98.
49. Ekman, P. & Friesen, W. V. (1978). *Facial action coding system: A technique for the measurement of facial movement*. Palo Alto, CA.: Consulting Psychologists Press.
50. Ekman, P., & Oster, H. (1979). Facial expressions of emotion. *Annual Review of Psychology*, 20, 527-554.
51. Ekman, P. (1972). Universals and cultural differences in facial expressions of emotion. In J. Cole (Ed.), *Nebraska Symposium on Motivation 1971*, (19, 207-283). Lincoln, NE: University of Nebraska Press.
52. Ekman, P. (1989). The argument and evidence about universals in facial expressions of emotion. In H. Wagner & A. Manstead (Eds.), *Handbook of social psychophysiology* Chichester: Wiley; 143-164.
53. Ferber, S., & Karnath, H.O. (2001). How to assess spatial neglect line bisection or cancellation tasks? *Journal of clinical and experimental neuropsychology*, 23, 599-607.
54. Fierro, B., Brighina, F., & Bisiach, E. (2006). Improving neglect by TMS. *Behav Neurol,* 17, 169–176.
55. Fischer, M.H. (1994). Less attention and more perception in cued line bisection. *Brain and Cognition,* 25, 24–33.
56. Fischer, M.H. (2001). Cognition in the bisection task. *Trends in Cognitive Science,* 5, 460–62.
57. Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). Mini Mental State. A practical method for grading the cognitive state of patiens for the clinician. *Journal of Psychiatric Research*, 12 (3), 189-198.
58. Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control setting. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 1030-1044.

59. Frijda, N. H. (1986). *The emotions*, Cambridge, University Press Cambridge.
60. Frijda, N. H. (1988). The laws of emotions. *American psychologist*, 43, 349-358.
61. Gallagher, S. (1995). Body schema and intentionality. In Bermúdez, J., Marcel, A., & Eilan, N. (Eds.). *The Body and the Self* (225-244). Cambridge, Massachusetts: MIT Press.
62. Gazzaniga, M.S., Ivry, R.B., & Mangun, G.R. (2005). *Neuroscienze cognitive*. Zanichelli editore.
63. Gottfried, J.A., O'Doherty, J., & Dolan, R. (2003). Encoding predictive reward value in human amygdala and orbitofrontal cortex. *Science*, 301, 1104–1107.
64. Graziano, M.S.A., & Cooke, D.F. (2006). Parieto-frontal interactions, personal space, and defensive behavior. *Neuropsychologia*, 44, 845-859.
65. Grèzes, J., Pichon, S. & de Gelder, B. in *Human Brain Mapping* (Florence, Italy, 2006).
66. Grèzes J., Pichon S., & de Gelder B. (2007). Perceiving fear in dynamic and body expressions. *NeuroImage*, 35(2), 959-67.
67. Grossi, D., Di Cesare, G., & Trojano, L. (2004). Left on the right or viceversa: A case of "alternating" constructional allochiria. *Cortex*, 40(3), 511-518.
68. Guariglia, C., Coriale, G., Cosentino, T., & Pizzamiglio, L. (2000a). TENS modulates spatial reorientation in neglect patients. *Neuroreport*, 11, 1945-1948.
69. Guariglia, C., Coriale, G., Cosentino, T., & Pizzamiglio, L. (2000b). TENS modulates spatial reorientation in neglect patients. *Neuroreport*, 11, 1945-1948.
70. Hadjikhani, N., & de Gelder, B. (2003). Seeing fearful body expressions activates the fusiform cortex and amygdala. *Curr. Biol.*, 13, 2201–2205.
71. Halligan, P. W., Marshall, J. C., & Wade, D. T. (1992). Left on the right: Allochiria in a case of left visuo-spatial neglect. *Journal of neurology, neurosurgery and psychiatry*, 55, 717-719.
72. Halligan. P.W., Marshall, J.C. (1988). Neglect of awarness. *Consciousness and cognition*, 7(3), 356-380.
73. Haxby, J.V., Hoffman, E.A., & Gobbini, M.I. (2000). The distributed human neural system for face perception. *Trends Cogn. Sci.*, 4, 223–233.
74. Head, H., & Holmes G. (1911). Sensory disturbances from cerebral lesion. *Brain*, 34, 102-254.
75. Heilman, K. M., e Valenstein, E. (Eds.) (1985). *Clinical neuropsychology*, Oxford, Oxford University Press.
76. Hermans, D, Vansteenwegen, D., & Eelen, P. (1999). Eye movement registration as a continuous index of attention deployment: Data from a group of spider anxious student. *Cognition & Emotion*, 13, 419-434.
77. Hillyard, S.A., & Anllo-Vento L. (1998). Event-related brain potentials in the study of visual selective attention. *Proc Natl Acad Sci USA*, 95:781–787.
78. Holland, P.C., & Gallagher. M. (2004). Amygdala-frontal interactions and reward expectancy. *Current opinion in Neurobiology*, 14, 148-155.

79. Hoschi, E., & Tanji, J. (2004). Area-selective neuronal activity in the dorsolateral prefrontal cortex for information retrieval and action planning. *J. Neurophysiol.*, 91, 2707-22.
80. Izard, C. E. (1977). *Human emotions*, Plenum Press, New York.
81. Izard, C. E. (1991). *The psychological of emotion*, Plenum Press, New York.
82. James, W. (1890), *The principles of psychology*, New York: Holt.
83. Jewell, G., & McCourt, M.E. (2000). Pseudoneglect: a review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia*, 38, 93-110.
84. Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.
85. Kanwisher, N., McDermott, J., & Chun, M.M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *J. Neurosci*, 17 (11), 4302–4311
86. Karnath, H-O, Ferber, S, & Himmelbach, M (2001). Spatial awareness is a function of the temporal not the posterior parietal lobe. *Nature*, 411, 950-953.
87. Karnath, H.O., Perenin, M.T. (2005). Cortical control of visually guided reaching: evidence from patients with optic ataxia. *Cereb.Cortex*, 15, 1561-1569.
88. Kastner, S., & Ungerleider, L. G. (2000). Mechanisms of visual attention in the human cortex. *Annual Review of Neuroscience*, 23, 315–341.
89. Kinsbourne, M. (1987). Mechanisms of unilateral neglect, in *Neuropsysiological and neuropsychological aspects of spatial neglect*, a cura di M. Jeannerod, Amsterdam, North-Holland, 5, 69-86.
90. Klein, R. M. & Ivanoff, J. (2004). *Inhibition of Return. Neurobiology of Attention*. Itti, Elsevier, 96-100.
91. Kret, M.E., Pichon, S., Grèzes, J., & de Gelder, B. (2011). Similarities and differences in perceiving threat from dynamic faces and bodies. An fMRI study. *Neuroimage*, 54(2), 1755-62.
92. LaBerge, D., & Brown, V. (1989). Theory of attentional operations in shape identification. *Psychological Review*, 96, 101–124.
93. Làvadas, E., Berti, A., & Farnè, A. (2000). Dissociation between conscious and non-conscious processing in neglect. In Y. Rossetti e A. Revonsvo. Beyond Dissociation. Interaction between dissociated implicit and explicit processing. Advances in consciousness research, Amsterdam, Benjamins, vol.XXII.
94. Làdavas, E., Paladini, R., & Cubelli, R. (1993). Implicit associative priming in a patient with left visual neglect. *Neuropsychologia*, 31, 307-320.
95. Làdavas, E., Petronio, A., & Umiltà, C (1990). The deployment of visual attention in the intact field of hemineglect patients. *Cortex*, 26: 307-317.
96. Ledoux, J. (1992). Emotion and the limbic System Concept. *Concepts in neuroscience*, 2, 169-199.
97. Mack, A., & Rock I. (1998). *Inattentional Blindness*. Cambridge, MA: MIT Press.
98. Mammuccari, A., Caltagirone, C., Ekman, P., et al. (1988). Spontaneous facial expression of emotion in brain damaged patients. *Cortex*, 24, 521-533.

99. Martin, M., Williams, R.M., & Clark, D.M. (1991). Does anxiety lead to selective processing of threat-related information? *Behaviour Research and Therapy,* 29, 147-160.

100. Mathews, A., & Klug, F. (1993). Emotionality and interference with color naming in anxiety. *Behavioral Research and Therapy,* 31, 57–62.

101. McCourt, M.E., & Garlinghouse, M. (2000), Asymmetries of visuospatial attention are modulated by viewing distance and visual field elevation: pseudoneglect in peripersonal and extrapersonal space. *Cortex,* 36, 715-731.

102. McGaugh, J.L. (2000). Memory-a century of consolidation. *Science*, 287, 248–51.

103. McGeorge, P., Beschin, N., Colnaghi, A. et al. (2007). A lateralized bias in mental imagery: evidence for representational pseudoneglect. *Neurosci Let*, 421(3), 259-63.

104. Miller, J. (1989). The control of attention by abrupt visual onsets and offsets. *Perception & Psychophysics*, 45, 567-571.

105. Mitchell, R.L. et al. (2003). The neural response to emotional prosody, as revealed by functional magnetic resonance imaging. *Neuropsychologia*, 41, 1410-1421.

106. Mogg, K., Bradley, B.P., & Hallowell, N. (1994). Attentional bias to threat — roles of trait anxiety, stressful events, and awareness. *Q J Exp Psychol A*, 47, 841–864.

107. Mogg, K., Bradley, B.P., DeBono, J., et al. (1997) Time course of attentional bias for threat information in non-clinical anxiety. *Behav Res Ther*, 35, 297–303.

108. Muller, H.J., & Rabbitt, P.M.A. (1989). Reflexive and voluntary orienting of visual attention: time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 315-330.

109. Oatley, K. (1997). *Psicologia ed emozioni*. Bologna: Il Mulino.

110. Ohman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review*, 108, 483-522.

111. Peelen, M. V., & Downing, P. E. (2005). Selectivity for the human body in the fusiform gyrus. *J. Neurophysiol.*, 93, 603–608.

112. Peelen, M.V., Downing P.E. (2007). The neural basis of visual body perception. *Nature Reviews Neuroscience,* 8, 636-648.

113. Pessoa, L., McKenna, M., Gutierrez, E. & Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention. *Proc. Natl Acad. Sci*., 11, 463.

114. Pessoa, L., Japee, S., Sturman, D., & Ungerleider, L.G. (2005). Target visibility and visual awarness modulate amygdala responses to fearful faces. *Cerebral Cortex*, 16, 366-375.

115. Pichon, S., de Gelder, B., & Grèzes, J. (2009). Two different faces of threat. Comparing the neural systems for recognizing fear and anger in dynamic body expressions. *Neuroimage*, 47, 1873-1883.

116. Pizzamiglio, L., Cappa, S. F., Vallar, Get al. (1989). Visual neglect for far and near extra personal space in humans. *Cortex*, 25, 471-477.

117. Pizzamiglio, L., Antonucci, G., Judica, et al. (1992). Cognitive rehabilitation of the hemineglect disorder in chronic patients with unilateral right brain damage. *Journal of Clinical and Experimental Neuropsychology*, 14, 901-923.

118. Plutchik, R. (1980). *Emotion: A Psychoevolutionary Synthesis*. New York: Harper & Row.

119. Pourtois, G., Grandjean, D., Sander, D., et al. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cereb. Cortex,* 14, 619–633.

120. Posner, M.I., & Rafal, R.D. (1987). Cognitive theories of attention and rehabilitation of attentional deficits. In Meier, R.J., Diller, L., & Benton, A.S. *Neuropsychological rehabilitation.* London, Churchill Livingstone.

121. Posner, M.I., & Snyder, S.H. (1975). Attention and cognitive control, In *Information processing and cognition*: The Loyola symposium. R. L. Salso R.L., Hillsdale, NJ, Erlbaum, 55-85.

122. Posner, M.I. (1980). Orienting of attention. *Quart. J. Exp. Psychol*., 32, 3–25

123. Posner, M.I., Rafal, R.D., Choate, L.S., et al. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology*, 2, 211–228.

124. Posner, M. I. *Chronometric explorations of mind.* Hillsdale, N.J.: Erlbaum 1978

125. Posner, M.I., Walker, J.A., Friedrich, F.J., et al. (1984). Effects of parietal injury on covert orienting of visual attention. *Journal of Neuroscience,* 4, 1863–1874.

126. Pribram, K.H. (1954). Towards a science of neuropsychology. In *current trends in psychologyand the behavioral sciences,* ed. Patton, R.A. Pittsburgh: University of Pittsburg Press.

127. Price, J., Russchen, F. T., & Amaral, D.G. (1987). The limbic region II: The amygdaloid complex. In *Handbook of chemical neuroanatomy,* Vol. 5, Integrated systems of the CNS, Part I, Hypothalamus, Hippocampus, Amygdala, Retina, Bjorklund, A. & Hokfelt, T. (Eds.). Amsterdam, Elsevier, 279-388.

128. Prigatano, G. P., & Schacter, D.L. (1991). *Awareness of deficit after brain injury: clinical and theoretical issues*. Oxford University Press. 53-55.

129. Reed, C.L., Stone, V.E., Bozova, S., et al. (2003). The body-inversion effect. *Psychol. Sci.,* 14, 302–308.

130. Reeves, A., & Sperling, G. (1986). Attention gating in short-term visual memory. *Psychological Review,* 93, 180–206

131. Riddoch, M.J., & Humphreys, G.W. (1983). The effect of cueing on unilateral neglect. *Neuropsychologia*, 2, 589–99.

132. Rinn, W.E. (1984). The neuropsychology of facial expression: A review of the neurological and psychological mechanisms for producing facial expressions. *Psychological Bulletin,* 52-77.

133. Rizzolatti, G., Gentilucci, M., & Matelli, M. Selective spatial attention: one center, one circuit, or many circuits? In Posner, M.I., Marin, O.M.S. (Eds.), Attention and Performance, XI. Conscious and Nonconscious Information processing. Hillsdale, NJ: Eribaum, 251-265, 1985.

134. Rizzolatti, G. & Berti, A. (1993). Neural mechanisms of spatial neglect. In Robertson I.H., & Marshall, J.C. (Eds.), *Unilateral neglect: Clinical and experimental studies* (87-106). Hove, U.K.: Erlbaum.

135. Robertson, I., H., & Halligan P.W. (1999). Spatial neglect. A clinical handbook for diagnosis and treatment. *Psychology Press Ltd*., Hove.

136. Robertson, I. H. & North, N. (1993). Active and passive activation of left limbs: influence on visual and sensory neglect. *Neuropsychologia*, 31, 293-300.

137. Rode, G., Charles, N., Perenin, M.T., et al. (1992). Partial remission of hemiplegia and somatoparaphrenia through vestibular stimulation *in a case of unilateral neglect*. *Cortex*, 28, 203- 208.

138. Rode, G., Klos, T., Courtois-Jacquin, S., et al. (2006). Neglect and prism adaptation: A newtherapeutic tool for spatial cognition disorders. *Restorative Neurology and Neuroscience*, 24, 347–356.

139. Schachter, S., & Singer, J. (1962). Cognitive, social, and psychological determinants of emotional state. *Psychological rewiew*, 69, 379- 399.

140. Schenkenberg, T., Bradford, D.C., & Ajax, E.T.. (1980). Line bisection and unilateral visual neglect in patients with neurological impairments. *Neurology,* 30, 509–17.

141. Shiffrin, R. M. & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 84, 127–190.

142. Selemon, L.D., & Goldman-Rakic, P.S. (1985), Longitudinal topography and interdigitation of corticostriatal projection in the rhesus monkey. *J. Neurosci*, 5, 776-794.

143. Semenza, C., & Goodglass, H. (1985). Localization of body parts in Brain Injurued subject. *Neuropsicologia*, 23, 161-75.

144. Sergerie K., Armony J. L. (2007). *Interazioni tra emozione e cognizione: una prospettiva neurobiologica.* In: Psicoanalisi e Neuroscienze, Mauro Mancia, Springer Milan.

145. Tamietto, M., Geminiani, G., Genero, R., et al. (2007). Seeing Fearful Body Language Overcomes Attentional Deficits in Patients with Neglect. *Journal of Cognitive Neuroscience*, 19, 3, 1-10.

146. Tamietto, M., Latini Corazzini, L., Pia, L., et al. (2005). Effects of emotional face cueing on line bisection in neglect: *a single case study. Neurocase*, 11(6), 399-404.

147. Tomkins, S. S. (1962). Affect, imagery, and consciousness: Vol 1 The positive affects, Springer, New York.

148. Tooby, J., & Cosmides, L. (1990). The past explains the present: Emotional adaptations and the structure of ancestral environment. *Ethology and Sociobiology*, 11, 375-424.

149. Treisman, A., & Gelade, G., 1980. A feature integration theory of attention. *Cognitive Psychology*, 12, 97-136

150. Treisman, A. (1988). Features and objects. *Quaranterly Journal of Experimental Psychology*, 40, 201-237.

151. Umiltà C. (1999). *Manuale di neuroscienze*. Editore Il Mulino.

152. Valenstein, E., & Watson, R.T. (1987). Hemispace and hemispatial neglect, *in Neuropsysiological and neuropsychological aspects of spatial neglect*, Jeannerod M. (Ed.), Amsterdam, North-Holland.

153. Vallar, G, & Perani, D. (1986). The anatomy of unilateral neglect after right-hemisphere stroke lesions. A clinical/CT-scan correlation study in man. *Neuropsychologia.* 24(5), 609–622.

154. Vallar, G., Rusconi, M. L., & Bernardini, B. (1996). Modulation of neglect hemianesthesia by transcutaneous electrical stimulation. *Journal of the International Neuropsychological Society*, 2, 452-459

155. van den Heuvel, O.A., Veltman, D.J., Groenewegen, H.J., et al. (2005). Disorder-specific neuroanatomical differentiation of emotional Stroop interference effects in obsessive-compulsive disorder, panic disorder and hypochondriasis. *Archives of General Psychiatry*, 62, 922-933.

156. Van de Riet, W.A.C., Grèzes, J., & de Gelder, B. (2009). Specific and common brain regions involved in the perception of faces and bodies and the representation of their emotional expressions. *Soc. Neurosci*, 4 (2), 101–120.

157. Vuilleumier, P., Armony, J.L., Driver, J., et al. (2001). Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. *Neuron,*, 30, 829–41.

158. Vuilleumier, P, & Schwartz, S. (2001). Emotional facial expressions capture attention. *Neurology,* 56, 153–58.

159. Vuilleumier, P., Valenza, N., Mayer, E., et al. (1998). Near and far visual space in unilateral neglect. *Annals of Neurology,* 43, 406–10.

160. Vuilleumier, P. (2004). Anosognosia: the neurology of beliefs and uncertainties. *Cortex*, 40, 9-17.

161. Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends Cogn. Sci*., 9, 585–594.

162. Vuilleumier, P., & Pourtois, G. (2007). Distributed and interactive Brain mechanisms during emotion face perception: evidence from functional neuroimaging. *Neuropsychologia,* 45, 174–194.

163. Vuilleumier, P. (2004). Anosognosia: the neurology of beliefs and uncertainties. *Cortex,* 40 (1), 9–17.

164. Williams, M.A., & Mattingley, J.B. (2004). Unconscious perception of facial emotion in parietal extinction. *Experimental Brain Research*, 154(4), 403-406.

165. Wilson, B., Cockburn, J., & Halligan, P. W. (1987). *Behavioral Inattention test,* Thames Valley test company, Bury St. Edmunds.

166. Wilson, B., Cockburn, J. e Halligan, P. (1987). Development of a behavioural test of visuospatial neglect. *Archives of Physical Medicine and Rehabilitation*, 68, 98-102.

167. Wolfe, J.M., Alvaraz, G.A., & Horowitz, T.S. (2000) Attention is fast but volition is slow. *Nature*, 406-691.

168. Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception & Performance*, 10, 601-621.