



## Research Article

# Understanding the relationships between Post-Traumatic Stress Disorder and Structural Personality Changes: Contributions from the Evolutionary Biology, the Cognitive Styles, and the Neural Network Theories

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## Abstract

### Introduction

There is a growing interest in a better understanding of the relationships between the long term effects of Post-Traumatic Stress Disorder (PTSD) and the development of Personality Disorders (PD). It has been suggested that trauma, symptoms of PTSD, and features of borderline personality disorder are related to each other in a complex fashion. This review is based on the idea that certain cognitive limitations in these subjects may be linked to specific neurobiological anomalies that can be targeted by neuroimaging techniques, which can shed some light on these topics.

### Methods

For preparing this systematic review, we have established the following actions:

To gather neuroimages on Post-Traumatic Stress Disorder and Personality Disorders,

To analyze the brain regions involved in these disorders.

To describe the known functions of these neuroanatomical regions.

To sort the abnormal clusters by principal functional networks and systems to which they pertain.

To suggest plausible integrative explanations for the physiological and cognitive functional changes that may have suffered the affected subjects, as the result of their traumatic experiences.

### Results

We present an inventory of 22 brain regions that show abnormal volumetric or metabolic activity in various reported cases of PTSD and/or PD, describing their known functions and relevance for explaining these pathologies.

### Conclusions

Various brain regions that show diminished activity have evolved lately, and sub-serve highly-complex cognitive and behavioral functions. The cerebral activity of these subjects may be representative of their associated cognitive styles. Neural Network Systems Theories posit that final synaptic weights result as a consequence of gradual modifications of initial-basal-weights towards final-better adapted, or goal-oriented- functional states. This process may be considered as a permanent systemic adaptation, originated by a succession of environmental situations that constantly triggers internal search processes towards optimal energetic distributions of the cerebral metabolic activity.

### Keywords

Neuroimaging; Personality disorders; Post-traumatic stress disorder

## Introduction

There is a growing interest in a better understanding of the relationships between the long term effects of Post-Traumatic Stress Disorder (PTSD) and the development of Personality Disorders (PD), especially of the borderline type [1-4]. Axelrod, among others, has suggested that trauma, symptoms of PTSD, and features of borderline personality disorder are related to each other in a complex fashion that may exceed simple linear models. High rates of comorbid PTSD, ranging from 26% to 57% have been found in subjects with borderline personality disorder (BPD), and for some researchers, these findings even suggest that this particular personality disorder (BPD) may actually be a variant of PTSD [5,6]. Neuroimaging studies on BPD seem to corroborate, at least partially, this hypothesis, as they also show the involvement of pre-frontal and limbic regions [7].

This report is based on the idea that certain cognitive limitations are linked to specific neurobiological anomalies (i.e.: memory impairment with hippocampal anomalies) [8].

Two main experimental conditions have been developed for the purpose of scientific research in this area: Most findings have originated in activation paradigms, in which one or more subjects are presented with strategically designed stimuli combinations (e.g.: trauma-evoking or symptom provocation, specific sensorial stimulation, memory tasks, etc.), comparing metabolic activity or regional

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cerebral blood flow through PET, SPECT or fMRI techniques in association with statistical methods, and looking for characteristic responses in specific brain regions. Specific patterns of cerebral activity have been also studied under low neuropsychological activation levels, or resting conditions. It has been observed that this last paradigm may account for a broad spectrum of cognitive changes that are frequently observed in long term PTSD patients, and which can be seen as persistent or structural personality changes [9-11]. In fact, PTSD affected subjects and PD affected subjects tend to perceive and behave in similar peculiar manners, not only under stressing or demanding situations, but when facing the circumstances of everyday-life.

## Methods

For preparing this systematic review, we have established the following actions:

1. To gather scientific literature on Post-Traumatic Stress Disorder and Personality Disorders neuroimages, and their similarities and common characteristics.
2. To analyze the brain regions involved in these disorders, with abnormally high or low metabolic activities.
3. To describe the known functions of these neuroanatomical regions, according to the current research reports.
4. In order to determine the involvement of neural networks and systems at an integration level, we sorted the abnormal clusters by principal functional networks and systems to which they pertain, considering hemispheric and Brodmann's locations, to which the abnormally activated clusters belong.
5. Finally, to suggest plausible integrative explanations for the physiological and cognitive functional changes that may have suffered the affected subjects, as the result of their traumatic experiences.

## Results

We gathered neuroimaging studies on PTSD and PD, in which there had been reported abnormalities in the hippocampus [8,12-17], the pre-frontal cortices [12,15,18-23], the anterior and posterior cingulate [12,14,15,18,19,24-26], the insular cortex [12,14,18-20], the cerebellum [20], the fusiform gyrus [12,14] and the precuneus [20].

In a review of van der Kolk [27], several structures that have been implicated in the pathophysiology of this illness are mentioned: parietal lobes [28], amygdala [18], hippocampus [8], corpus callosum [29,30], cingulate gyrus [24,18] and prefrontal cortex [27]. De Bellis et al. have reported volumetric abnormalities in temporal superior gyri. Ursano et al., Fernandez et al. and Bonne et al. and have reported functional cerebellar abnormalities [20,21,31,32]. Lanius et al. have found abnormalities in: anterior cingulate, thalamus, superior frontal gyrus, right parahippocampal gyrus, right superior occipital gyrus, right insula, left parietal lobe, right middle frontal gyrus, superior temporal gyrus and right cuneus [23,33]. Shin et al. have reported functional anomalies in orbito-frontal cortex, temporal poles, insular cortex, anterior cingulate gyrus, anterior frontal regions and left inferior frontal gyrus [22].

In a study of Molina et al., conducted under resting conditions, the authors found 33 clusters presenting abnormal metabolic activation in a PTSD group vs. a control group. Remarkable decreased

activity was found in: left cingulate (posterior), right lingual gyrus, bilateral dorsolateral prefrontal cortex, left parietal inferior gyrus, left post central gyrus, right precuneus and right insula [34]. Moderated decreased activity was found in: left temporal superior and medial gyri, right hippocampus, bilateral frontal medial gyrus, right frontal superior gyrus, right calcarine and left temporal inferior gyrus. Mild decreased activity was found in: bilateral cingulate gyrus (anterior), right parietal inferior, right post central gyrus (2 areas), left occipital medial and superior gyri, and right frontal medial gyrus. Only 11 out of the 33 abnormal clusters mentioned above showed a relative metabolic increase in PTSD subjects compared to controls. Remarkable increased activity was found in: bilateral fusiform gyrus and left precuneus. Moderated increased activity was found in: right temporal pole and right superior gyri, right post central gyrus, right temporal medial gyrus, left fusiform gyrus, right occipital medial and inferior gyri. Mild increased activity was found in: left lingual gyrus, left cerebellum and left temporal inferior gyrus. Results in Molina et al. seem to be consistent with those of many functional studies obtained under activation paradigms. Moreover, as there seems to be a logic direct correlation between a regional volume increase and an augmentation in regional glucose absorption, various MRI volumetric findings also appear to be in consonance with Results in Molina et al. [34]. However, it is necessary to remind that volumetric findings can only cautiously be related to functional findings, as it is suggested from Magistretti [35].

Two structures that have been reported as abnormal in previous activation studies of PTSD and stress-related disorders, did not show abnormal glucose absorption under resting conditions in Molina et al.: the thalamus and the amygdala [15,17,18,19,22,23,33,34,36].

Abnormally activated areas reported in this study and their potential cognitive and behavioral manifestations

**Limbic and prefrontal systems:** Many researchers have suggested that the limbic system constitutes the organizational space of memory, emotions, and motivations of the human being. In the model of Yakovlev, the limbic system reaches its maximal development in primates and constitutes an integration centre of the vital biological needs that are mediated by stem and deep, reticular-cerebral nuclei, and the storing and modelling systems mediated by the brain cortex [37]. Limbic structures participate in information coding and long-term memory transference functions [38-43]. In Molina et al., two regions of the limbic system presented a remarkable subnormal activity in PTSD subjects: the cingulate gyri and the precuneus [34].

- **Cingulate gyri:** The cingulate gyri are deep cortical structures that surround the corpus callosum and that have evolved, phylogenetically, through two phases: the anterior region (periamygdaloid) which developed firstly, and the posterior region (perihippocampal) which developed lastly. Both regions operate coordinately: the anterior cingulate gyri-affected bilaterally in Molina et al. assess the emotional meaning of a certain situation, with regards to the conservative mechanisms of the individual, and the posterior cingulate gyri-affected in the left hemisphere in Molina et al. receive a codification of this affective valence to associate its concurrent, sensorial perceptions [35]. As a result, the experiences of the individual are coded in memory with a modality that depends on the subjective, emotional load that every subject assigns to it, which, in turn, depends on genetic issues and vital, cumulative experiences [38-42,44-47].

- **Precuneus:** Papez and MacLean suggested that the precuneus should be considered part of the limbic system [48,49]. This region corresponds to a multimodal associative region, which processes the information that arrives through somatic sensitive paths, along with visual and auditory stimuli. Integrating this information is important to build visuospatial perceptions (location of objects, speed, three-dimensional deepness, etc.) and permits the individual to recognize the environment and to interact with it [50,51]. Studies on hemispheric specialization have shown that these functions take place, mainly, in the right hemisphere, and that this region is also strongly interconnected with thalamic magnocellular structures that are, phylogenetically, erstwhile [52]. The profuse connectivity of this area, that resembles that of pre-frontal regions, suggests a recent phylogenetic acquisition. Its destruction –a fact that often occurs because of strokes- determines a neurological condition named “neglect with contra lateral agnosia” [52]. Interestingly enough, the contra hemispheric precuneus –on the left- showed increased activation. In most right-handed subjects, as verbal abilities have emerged in the left hemisphere, visuospatial abilities have correspondingly emerged in the right hemisphere (Is this a neurophysiological compensation of the activity reduction in the former?).

**Insula:** Flynn et al. have found that the anterior insula is comprised of an agranular allocortical area which functionally is part of the paralimbic belt. Sub-cortical, limbic, and brain stem connections underscore the anterior insula’s role in processing and integrating autonomic and visceral information [53]. The posterior insula is comprised of a granular isocortical area which functionally is linked to somatomotor systems. Insular cortical and sub cortical connections, especially with the thalamus and basal ganglia, underscore the posterior insula’s role in somatosensory, vestibular, and motor integration. The predominant flow of intra-insular projections from anterior to more posterior regions suggests that the posterior insula also serves as an integrative heteromodal association area for information received by all five senses. The insula plays a role in cardiovascular, gastrointestinal, vestibular, olfactory, gustatory, visual, auditory, somatosensory, and motor modulation. It is also felt to play a role in conditioned aversive learning, in motivational components of pain perception, stress induced immunosuppression, mood stability, sleep, and language [53].

**Hippocampus:** Hippocampal regions participate in conferring chronological status to the mnemonic registers of the brain cortex [8,38,39,51,54]. If rightful negotiations of memory historicity-or sequencing–does not befall, mnemonically registers may emerge in a disorganized mode, either to irrupt in an abrupt manner or to be unsusceptible of evocation, partially or totally. This might be the reason why traumatic episodes are randomly re-experienced in a vivid fashion, or momentarily blanked from memory. Thus, said experiences seem to abide in an idle state of storage, inadequately prevailing on a cuasi-sensorial level. Bremner et al. have reported that combat veterans and victims of childhood abuse experience physical changes to the hippocampus [55]. As they refer, the hippocampus has the capacity to regenerate neurons as part of its normal functioning –it has been found that stress impairs this functioning by stopping or slowing down neuron regeneration in monkeys [56]. Bremner et al. conducted a study testing Vietnam combat veterans with declaratory memory problems caused by PTSD [8]. These combat veterans were found to have an 8% reduction in right hippocampal volume, measured with

magnetic resonance imaging (MRI). Their study showed that this fact was associated with short-term memory loss. Gilboa et al. conducted functional magnetic resonance imaging to study brain regions implicated in retrieval of memories that were decades old [57]. They found that context-rich memories were associated with activity in lingual and precuneus gyri independently of their age. By contrast, retrosplenial cortex was more active for recent events regardless of memory vividness.

**Prefrontal cortex:** Experimental data shows that the hippocampus works closely with the medial prefrontal cortex, an area of the brain that regulates the emotional response to fear and stress. Bremner et al. posit that PTSD sufferers often have concomitant impairments in both the hippocampus and the medial prefrontal cortex [12]. The prefrontal cortex has long been suspected to play an important role in cognitive control, in the ability to orchestrate thought and action in accordance with internal goals [58-61].

- The medial-frontal gyrus (BA 10) is an especially large brain area in humans that presented a reduced activity in the PTSD group. The participation of this area has been proved, by neuroimaging studies, from the simplest to highly complex tests involving memory and judgement, problem-solving, verbal and nonverbal episodic retrieval, semantic memory, language, motor learning, rule learning, verbal and nonverbal working memory. Burgess et al. have gathered experimental evidence on that the rostral prefrontal cortex sub serves a system that biases the relative influence of stimulus-oriented and stimulus-independent thought [62]. This cognitive control function (and its product) is used in a wide range of situations critical to competent human behaviour in everyday life. This area presented a reduced metabolic activity in the right hemisphere of PTSD patients in Molina et al [34].
- BA 45, in the left inferior-frontal gyrus -and in contra-hemispheric white matter proximate to BA 10 and BA 45- also showed low metabolic activation. BA 45 is part of the Broca’s Area [63]. In some functional neuroimaging studies, activations in this region also occur during semantic tasks for the generation of words to semantic cues or the classification of words or pictures into semantic categories. [64].

**Visual occipital regions:** The right lingual gyrus, the gyri surrounding the right calcarine fissure, and the left occipital medial and superior gyri showed reduced metabolic activity. These areas participate in primary and associative visual processes. Their contra hemispheric homologous showed augmented activation. The lingual gyrus participates in form and colour detection and, lastly, in the visual recognition of objects. From a phylogenetical point of view, this structure has evolved after the precuneus, and is associated to parvocellular thalamic structures [51].

**Auditive temporal regions:** The medial-temporal gyrus is an auditory associative area, especially relevant to perceptive language processes. The relative reduction of metabolic activity we observed in the left region of PTSD subjects is opposed to the metabolic increase in the right hemisphere. This region is thought to be involved in the assignment of subjective meaning to the auditory signals and in the construction of semantic expressions, principally, in the left hemisphere [65]. Paller et al. have gathered evidence of that this region is also involved in face recognition [66]. According to Bartmess-LeVasseur

et al. deductive processing rules are coded in temporal regions of the right hemisphere in a similar manner that linguistic processing rules are coded in the left [67].

**Multimodal temporal regions:** Certain temporal gyri participate in complex visuo-auditive associative processes:-

- The fusiform gyri (BA 37) -remarkably hyper activated (bilaterally) in PTSD patients in Molina et al are thought to be involved in functions such as face detection and recognition, the distinction between animated and unanimated objects, and spatial orientation [34,68-70]. Pursuant to Jobard et al., this region takes part, in conjunction with the inferior temporal gyrus, in the “verbalization” of the visual information, a form of graphical-phonological conversion that befalls in the Wernicke’s area [71,72].
- The right temporal pole (BA 38) -hyperactive in PTSD patients- is an associational cortical area in the anterior pole of the temporal lobe. It is involved in emotion valence attribution and in limbic associational integration, due its relations with networks of the amygdala and the orbital prefrontal cortex. Lexicosemantic processes are also attributed to these gyri, as semantic dementia is originated in neural loss of these areas [73,74]. Dissociative states have been linked to the hyper activation of superior and middle temporal gyri [33]. Temporal poles have also been related to complex sound analysis, as music and harmonization perception and production [75].
- De Bellis et al. reported that the temporal superior-gyri are significantly augmented in volume -especially in the right hemisphere- in children and adolescents who have been diagnosed with PTSD and have suffered physical abuse [76]. These findings appear to be consistent with Results in Molina et al. [34]. As mentioned, however, it is necessary to remind that volumetric findings can relatively be related to functional findings. The superior-temporal gyri (BA 22) have been associated to primary auditory functions, and to the establishment of phonological loops [64]. Its participation in functions that are linked to language processing has been known for a long time, principally, in the left hemisphere -hypoactive in our patients. This area also seems to be associated to auditive hallucination production in some epileptic patients [77]. Liebenenthal et al. have also studied the participation of this cortical area in the detection of audible frequency deviations, using evoked potentials, which is consistent with the reports of Poeppel et al. in relation to the functions of this area for discriminating the originating directions of audible tones [78,79]. Another process that occurs in this area, which has been recounted by McIntosh et al. is the interaction that it can exert over several occipital cortex regions [80]. Accordingly, the auditive stimuli would activate primary and associative occipital visual sectors that would be inactive otherwise.
- The inferior temporal gyrus (BA 20) integrates and transmits signals originated in the occipital visual cortex to project them towards the orbital frontal sectors [38,39,81,82]. Its metabolic activity seems to have shifted inside the left region itself.

**Language-related networks:** As we mentioned, left BA 45 is an area that participates in motor organization of language, and facilitates speech fluency. As the temporal area BA 22 also showed diminished activity, it was clear that the whole language network had become

abnormal in these patients. Here, again, a counterpart region -in the right hemisphere- showed an opposite metabolic activation pattern, rekindling the question on contra lateral regions’ activation, with their biological meaning.

**Cerebellum:** Prima fascie, cerebellar hyper activation may be surprising. Motor, postural, and autonomic functions of the cerebellum are well known, but as this study was conducted under basal conditions, few of these functions would, presumably, be under execution [83]. Actually, there is increasing evidence on the involvement of the cerebellum in some cognitive processes, such as visual contrast discrimination, face recognition and spatial orientation [65,84,85]. According to Bonne et al., the cerebellum maintains a spatial alert tone, necessary to free pre-motor cortex from the motor processes that can be automated [32]. The former have reported cerebellar metabolic hyperactivity as the most remarkable finding in a study in which they compared PTSD patients to a healthy control group, under a basal state. Fernández et al. have reported an evident metabolic augmentation in cerebellar activity in a case of a war veteran who suffered tortures [20]. Ursano et al. have also reported cerebellar hyper activation in PTSD patients, and suggested that this finding relates to biological and psychological responses of this disorder [31]. They sustain that cerebellar functioning is critical for spatial orientation and timing perception. Once again, some kind of compensation mechanisms may be suggested here. Is there a compensation mechanism tending to restore temporo-spatial orientation processes from precuneus dysfunction and visual recognition from temporo-occipital abnormalities? Is there a compensation mechanism in which the cerebellum relieves pre-motor or pre-frontal cortices’ activity, under certain circumstances? In support of these possibilities, Schmahmann et al. posit that the brain and the cerebellum operate in a complementary fashion [86]. He has determined that there is a strong and consistent input to the basis pontis from the association areas in the cerebral cortex and that these projections are derived from the posterior parietal, dorsolateral and dorsomedial prefrontal, superior temporal polymodal, and paralimbic cortices in the posterior parahippocampal region.

**Pre-motor regions:** The right oculo-motor and the pre-motor (bilateral) areas (BA 8 and BA 6) are other frontal regions that showed low metabolic activation. No pre-motor areas showed increased metabolic activation.

**Somatosensitive regions:** Three clusters from primary somatosensitive regions showed low activation (bilateral) (BA 3, post-central gyri). These regions are involved in somatotopic body representation [51]. No primary somatosensitive regions showed increased metabolic activation.

**Multimodal (parietal) areas:** Two clusters from parietal paraverbal areas: BA 40 (bilateral), near BA 39, showed diminished activity. One cluster, in right BA 40, close to BA 42, showed high metabolic activity in PTSD patients. These areas are thought to be involved in motor-auditive associations [38]. The supramarginal gyrus (BA 40) has a high probability of connection with the ventral pre-motor cortex [87]. In a comparative study of the long-term effects of sexual abuse on brain function, Bremner et al. have reported decreased blood flow in supramarginal gyrus, concomitant with decreased blood flow in right hippocampus, fusiform/inferior temporal gyrus, and visual association cortex in women with PTSD relative to women without PTSD [12]. These results seem to be compatible with ours, in spite of the fact that they have been obtained under a different experimental paradigm.

### The thalamus and the amygdala:

The thalamus has a relevant participation in the conduction of sensorial information. It is the largest portion of the diencephalon, and is located above the hypothalamus. It contains nuclei that project information to specific regions of the cerebral cortex, and receives information from it [51].

The amygdala is a structure located in the interior of the rostral temporal lobe, which contains a set of nuclei. It is part of the limbic system. The overt behaviors, the autonomic responses, and the hormonal secretions associated with emotional reactions are controlled by separate neural systems. The integration of these responses appears to be controlled by the amygdala [51]. A major description of the structure and functions of the amygdaline nuclei, along with their clinical relevance, is developed in Mega et al. [40]. Research antecedents and further information may be found in Goldar, Kagan Heilman and Watt [38,39,41,42,44].

### Discussion

Our findings support the hypothesis of Shulman on the possibility of detecting and analysing certain cerebral activities and functions under resting conditions by means of functional neuroimaging methods [88]. The cerebral metabolic activity patterns we have found in long term PTSD patients, under this paradigm, are presented in Table 1, along with their potential neuropsychological manifestations.

| Network and Systems  | Cognitive and Behavioural Traits Potentially related  |
|--|---|
| Limbic system: Anterior and posterior cingulate, Insula                | Emotional disorganization and deregulation, Demotivation, Corporal and psychological estrangement   |
| Limbic system: Hippocampus   | Amnesia, Memory consolidation problems, Intrusive memories, Autobiographical strangement, Fragmented sense of self and identity   |
| Limbic system: Precuneus, Multimodal (parieto-temporal) areas          | Abnormal perception, Abnormal spatio-temporal orientation, May also be related to fragmented sense of self and confusional and/or dissociative states, Contra lateral negligence disorder |
| Dorsolateral prefrontal cortex, BA 45                                  | Working memory dysfunction  |
| Prefrontal BA 10   | Every-day-life limitations and decision making  |
| Cortical primary sensitive areas (temporo-parieto-occipital), Insula   | Abnormal sensation (somatic, visual, auditive), Reduction of nociceptive sensations, May also be related to fragmented sense of self  |
| Left Dorsolateral prefrontal cortex BA 45, Left Temporal BA 22, Insula | Language disorders, Verbal comprehension, motivation and production (Broca's and/or Wernicke's aphasias)  |
| BA 6 and BA 7  | Attentional disorders   |
| BA 6 and BA 8  | Motor disorders   |
| Multimodal (parieto-temporal) areas, Insula.                           | Agnosias, apraxias, agraphias, prosopagnosias, Abnormal object recognition  |
| Right temporal areas and cerebellum                                    | Auditive hyper sensibility  |
| Cerebellum   | Hyper vigilance, spatial alertness, attentional exacerbation  |
| Right superior temporal gyri   | Visual processes abnormally triggered by auditive stimuli   |
| Right Lingual gyri   | Abnormal visual object recognition and detection  |

**Table 1:** Theoretical relationships between neural activation patterns evidenced by this investigation and their potential cognitive and behavioural manifestations.

It seems possible to correlate these neurobiological characteristics with specific personality traits, in consonance with the structural personality changes observed by Nijenhuis and the studies of Alarcon, who has suggested that the persistent change or transformation of the personality after a catastrophic experience is characterized by a sustained change in the manner of perceive, relate, and think about oneself and the others, and Grbesa who has observed that the symptoms of PTSD show an evolution from acute form to chronic form and finally to structural personality changes [9,11].

We may infer that the basal cerebral glucose absorption patterns of these patients represent a shift towards a theoretical state in which it is possible to identify language limitations (verbal and paraverbal areas), memory impairments (hippocampus), low impulse control-probably associated to some social interacting difficulties (limbic system, pre-frontal cortices and pre-motor regions), anhedony and loss in motivation (limbic system and pre-frontal cortex), and a sustained physical and emotional alertness state (cerebellum and visual and auditive regions), accompanied by rapid physical reactions (cerebellum and pre-motor cortex).

### Perspectives from the evolutionary biology

From a philogenetic and an ontogenetic standpoint, various brain regions that show diminished activity (limbic, frontal and prefrontal cortex, multimodal parieto-occipital areas and verbal and paraverbal areas) have evolved lately, and sub-serve highly-complex cognitive and behavioral functions. The powerful processing information that these regions confer to the organism, represents a high cost for it in terms of time and energy.

From an adaptation standpoint, the nervous system of PTSD patients seems to have conformed to a specific, extremely violent environment, in which the brain needs to meet certain crucial abilities: a) To build perceptual constructs fast, mainly from auditive and visual stimuli, b) To promptly generate adequate motor sequences, and c) To administer brain and body energy in a conservative fashion.

These hypotheses derive from the following analysis:

- When the stressful aversive situation is not lethal, survival does not depend on escape but rather on conservation of energy [89].
- Metabolic activity has increased in multimodal temporo-occipital areas, which yield preeminence to acoustic and visual sensation and perceptions over somato-sensitive and verbal performance.
- High metabolic activity in the cerebellum has been related to alertness and reactivity. The increased activity of the cerebellum suggests that it may have taken relief of certain pre-motor cortical functions.
- In a similar fashion that some neural structures may take relief of others, it is also possible for certain cerebral signals to be shared among different neural circuits and systems. So, if fast cerebellar operation take precedence over that of cortical structures because motor responses are to be generated faster, the information flux towards cortical regions may have resulted restricted. It is also possible that the inhibitory functions that the pre-frontal cortex should exert over other circuits and systems have resulted depressed.
- The apparently normal metabolic activity of the amygdala, indicated by Results in Molina et al. supports the hypothesis of Bremner et al., on a primary dammage in pre-frontal systems in PTSD patients [12,34,90].

- Certain environmental situations need to be assessed in terms of their potential risk for the organism. Once a potential dangerous situation has been evaluated as innocuous, it is necessary that pre-frontal regions provide adequate control signals to the amygdala to inhibit its over-excitation. A failure in this balancing circuit may result in excessive alert signals-triggering. This might explain why the amygdala of PTSD patients is more reactive than those of normal controls, and shows significant delays when discriminating between real dangerous situations from danger evocating ones.

### Perspectives from the Cognitive Styles Theories

The basal cerebral metabolic activity of these subjects may be representative of their associated cognitive styles. The concept “cognitive style” refers to the way people search for, acquire, interpret, categorise, remember, and retrieve information in making decisions and solving problems [91].

PTSD patients have shown to present serious deficiencies in all these areas. Moreover, cognitive style has long been implicated as a risk factor for depression and suicidal behavior. More precisely, there are indications that suicide is associated with a constriction in cognitive style. This constriction leads to disturbances in problem-solving and information processing [91]. Alloy et al. have also reviewed evidence on that depressogenic cognitive styles confer vulnerability for clinically significant depressive disorders and suicidality [92].

Due the high rates of suicides that have been reported among PTSD patients, there is an urgent need of understanding how these patients communicate, process information, and may be stimulated to learn new problem-solving techniques. The neurobiological involvement of language areas represents an additional challenge for establishing better communication strategies with these patients.

Cognitive style approaches have provided tools and techniques that might be explored to develop new specific therapeutic strategies for PTSD.

### Perspectives from the neural network theories

Cognitive styles strongly depend on the disposition that the neural networks of the nervous system have reached under the influence of genetic and environmental factors. In other words, nor two human beings share exactly the same neural disposition and nor two human beings share the same manner of perceiving and reacting to the world.

Neural Network Systems Theories posit that final synaptic weights result as a consequence of gradual modifications of initial –basal-weights towards final – better adapted, or goal-oriented- functional states. This process may be considered as a permanent systemic adaptation, originated by a succession of environmental situations that constantly triggers internal search processes towards optimal energetic distributions of the cerebral metabolic activity. This permanent adaptation process is made possible through what is known as “neural plasticity”, i.e. the capabilities of the neural networks and systems to self-modify their connectivity in order to achieve new outcomes, under the constrictions established by the actual biophysical dispositions of the neural systems.

From a social perspective, however, reaching an objective optimal state is not a so-directly-derived concept. Social adaptation is a subjective concept, and social interactions do not always elicit the

most convenient responses in mentally disturbed patients, at least from what is socially accepted. A better way to understand social adaptation processes in mentally ill persons would be to understand these plastic connectivity explorations of the neural networks as a seek for new feasible states instead of new optimal states. Adaptation, as a whole complex process, depends on possible initial states and possible final states, and these possibilities are given by specific dispositions of the neural systems: their complexity, connectivity, robustness, functionality and plasticity, and many of these features may be temporarily or permanently affected by mental disease. Thus, it is possible to infer that basal regional glucose absorption patterns of patients with specific disorders should be informative of the neurobiological substratum of the illness, upon which ulterior potential neural adaptation processes might take place.

### Conclusions

We have found evidence of neurobiological abnormalities in long term PTSD and in PD diagnosed subjects, my means of different neuroimaging techniques.

Our aim, in moving from “abnormal clusters and regions” towards “dysfunctional networks and systems”, has been that of moving from “signs and symptoms” to “personality traits”. It has been possible to correlate the neurobiological characteristics of long term PTSD patients to structural personality changes, as the observed theoretical typology is concordant with the structural personality changes that have been described in previous works.

Our findings support the hypothesis of a primary neurobiological damage in pre-frontal and limbic structures in the brain of PTSD patients. The excessive metabolic reactivity that the amygdala shows in these subjects may be originated in the reduction of discriminant inhibitory signals from prefrontal and limbic regions, which have been depressed in favor of sensorial and cerebellar performance.

Approaching Personality dimensions and constructs makes possible to investigate new therapeutic approaches. Personality changes imply cognitive styles changes, and indicate the need of new strategies to communicate with these patients and to better understand the way in which they relate with themselves and others.

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### Competing Interest

No competing interests to declare.

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