CASE STUDY

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# EVENT-RELATED POTENTIAL STUDIES OF COMBINED MILD TRAUMATIC BRAIN INJURY/POST-TRAUMATIC STRESS DISORDER IN A RETIRED POLISH ARMY LIEUTENANT COLONEL

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## SUMMARY

**Background** The extensive Medline search performed allowed us to state that the majority of reports support evidence of information processing abnormalities in patients with Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder.Studies of event-related potentials (ERPs) are the main tool in any real time examination of information processing in miliseconds. Based on the available data, and our own research, we suggest that QEEG and ERPs abnormalities may result in a better understanding of the mechanism by which the symptoms of these disturbances overlap with each other.

**Case study:** The patient, a 57-year-old man, retired Polish Army lieutenant colonel, who had seen active service twice in Lebanon, was diagnosed with Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder, in accordance with the DSM 5 criteria. MR neuroimaging research showed cerebral-subcortical structural dystrophy. The neuropsychological tests confirmed an increasing degree of disturbance within cognitive and emotional processes as well as behavioural disturbances. Through the appliance of QEEG methodology as well as the potentials connected with the event (ERPs) it appeared that: (1) rare low-voltage rapid EEG occured; (2) increased activity in the subcortical areas, (3) weakened activity in the cerebral areas. The patient completely lost cognitive and emotional control which meant that he was unable to function in everyday life.

**Conclusions:** The conducting of ERPs on the patient made it possible to understand the brain mechanisms lying at the basis of the overlapping symptoms of Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder. The appearance of a low-voltage, rapid EEG could possible be a factor enhancing the development of PTSD, particularly in patients who have experienced Mild Traumatic Brain Injury. The results obtained show the need to exclude low-voltage EEG in soldiers despatched to see service in regions of armed conflict.

**Key words:** attention, memory, executive functions, flashback

# INTRODUCTION

Of immense danger is any force which
is not accompanied by a sense of responsibility.
*Archibald Joseph Cronin*

**Posttraumatic stress disorder** (PTSD), constitutes at the present moment a new challenge for medicine worldwide. As a result of the increased incidence of terrorist attacks and armed conflicts in the world there is an rise in the number of people who suffer from PTSD. However, it is difficult to estimate statistically the rate of PTSD both in Poland as globally, particularly given that with the publication of a new handbook on the classification of psychiatric diseases DSM 5 [1,2], the diagnostic criteria adopted for this syndrome have changed.

Often cited within the subject literature are data from the United Nations' World Health Organization, which publishes estimates of PTSD impact for each of its member states; the latest data available are for 2004. Considering only the 25 most populated countries ranked by overall age-standardized Disability-Adjusted Life Year (DALY) rate, the top half of the ranked list is dominated by Asian/Pacific countries, the US, and Egypt [2]. However, it is worth noting that the above given statistics do not merely cover war veterans but equally those who have fallen foul of PTSD for other reasons.

Statistics on war veterans have been published by the United States Department of Veterans Affairs, which estimates that 830,000 Vietnam War veterans suffered symptoms of PTSD [3,4,5]. The National Vietnam Veterans' Readjustment Study (NVVRS) found 15.2% of male and 8.5% of female Vietnam veterans to suffer from current PTSD at the time of the study.

At the beginning of the second decade of the 21$^{st}$ century further cohort studies were conducted. Researchers from Georgia State University and San Diego State University found that rates of PTSD diagnosis increased significantly in 2011, when troops were stationed in combat zones, had tours of duty of longer than a year, experienced combat, or were injured. Military personnel serving in combat zones were 12.1 percentage points more likely to receive a PTSD diagnosis than their active-duty counterparts in non-combat zones [4,5]. The studies conducted showed the marked significance of the time duration exposue to stress-inducing events. Those serving more than 12 months in a combat zone were 14.3 percentage points more likely to be diagnosed with PTSD than those having served for less than one year. It is important to add that experiencing enemy firefight was associated with an 18.3 percentage point increase in the probability of PTSD, while being wounded or injured in combat was associated with a 23.9 percentage point increase in the likelihood of a PTSD diagnosis. For the 2.16 million U.S. troops deployed in combat zones between 2001 and 2010, the total estimated two-year costs of treatment for combat-related PTSD are between $1.54 billion and $2.69 billion [5].

The latest reports which may be found in the subject literature globally concerning the epidemiology of PTSD are ones from 2013 [6]. The authors have estimated the value as being at up to 20% of veterans returning from Iraq and Afghanistan. Yet these data already point to the fact that the very diagnosis and treatment of individuals with PTSD is a calling for the medical profession globally, particularly in those countries which are torn by armed conflict. An even greater problem involves soldiers who display both Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder. The new statistics will be introduced on the basis of a DSM 5 diagnostic classification [1], and for this reason we have adopted this classification equally in the diagnosis of our patient.

Posttraumatic stress disorder, in accordance with the DSM 5 classification, [1] is considered to be a form of fear disturbance connected with a short- or long-term exposure to a traumatic event which (1) possess features exclusively threatening or that are catastrophic in nature, (2) that exceed the limits of human indurance. Traumatic events of this magnitude are considered to be:

- participation in front-line fighting;
- being the victim/or witness of bombardment, torture in concentration camps, and finally acts of terrorism [so-called man-made disorders];
- being the victim and/or witness of a transport catastrophy,
- being the victim and/or witness of flooding, particularly when personal loss is involved
- a tragic accident in which someone close has died
- being the victim of rape, sexual harassment, or an attack with violence.

In turn a mild TBI, otherwise known as a concussion, is caused by a blow or jolt to the head that disrupts the function of the brain [7]. Academic studies conducted have shown that many members of the U.S. Armed Forces in Iraq and Afghanistan have sustained brain injuries from attacks with weapons such as rocket propelled grenades, improvised explosive devices, and land mines [3]. Others have been involved in motor vehicle crashes or other trauma that resulted in brain injuries. Mild TBI is difficult to diagnose in civilian practice and can be hard to diagnose after a service member has returned home. Complaints after sustaining a mild TBI, often referred to as post-concussion symptoms, include headache, dizziness, nausea/vomiting, trouble in concentrating, memory problems, irritability, fatigue, ringing in the ears and sensitivity to noise and light. In a small percentage of people, symptoms may persist for months or years [7].

The subject literature emphasises the importance of conducting a differential diagnosis [1]. Attention is drawn to how a diagnosis of PTSD requires exposure to an extreme stressor such as one that is life-threatening. It is pointed out that any stressor can result in a diagnosis of a adjustment disorder and it is an appropriate diagnosis for a stressor and a symptom pattern that does not meet the criteria for PTSD. If any of the symptom pattern is present before the stressor, another diagnosis is required, such as a brief psychotic disorder, drug-induced psychotic disorder, obsessive compulsive disorder for intrusive thoughts that are recurring but not related to a specific traumatic event, a major depressive disorder, schizophrenia

or other disorders with psychotic features such as psychotic disorders due to a general medical condition. There also exists the necessity for a differentiation of malingering if a financial and/or legal advantage is a possibility [1,5,6,7].

# BIOCHEMICAL RESEARCH

Neurophysiological tests are linked to the fact that PTSD is viewed as a specific form of memory disturbance, in which the intrusive reconstruction of traumatic events is accompanied by an increased level of adrenalin, which may result in a strengthening of memory traces. These patterns can persist long after the event that triggered the fear, making an individual hyper-responsive to future fearful situations [8,9]. During traumatic experiences the high levels of stress hormones secreted suppress hypothalamic activity that may be a major factor toward the development of PTSD [10,11].

Yehuda et al. [12,13] have observed that PTSD causes biochemical changes in the brain and body, ones that differ from other psychiatric disorders such as major depression. The authors suggested that individuals diagnosed with PTSD respond more strongly to a dexamethasone suppression test than individuals diagnosed with clinical depression.

In addition researchers also conjecture that most people with PTSD also show a low secretion of cortisol and high secretion of catecholamines in urine [14], with a norepinephrine/cortisol ratio consequently higher than comparable non-diagnosed individuals [15]. It should be pointed out that this is in contrast to the normative fight-or-flight response, in which both catecholamine and cortisol levels are elevated after exposure to a stressor [16].

Works may also be found in which it is shown that brain catecholamine levels are high [17], and corticotropin-releasing factor (CRF) concentrations are high [18,19]. However, it is worth emphasising that all this research suggests abnormality in the hypothalamic-pituitary-adrenal (HPA) axis.

This was known earlier as Yehuda states [20,21], and which finds reflection in the latest pieces of research [22], that the HPA axis is responsible for coordinating the hormonal response to stress. Given the strong cortisol suppression to dexamethasone in PTSD, HPA axis abnormalities are likely predicated on a strong negative feedback inhibition of cortisol, itself likely due to an increased sensitivity of glucocorticoid receptors [23].

If we translate this reaction to human conditions it gives a pathophysiological explanation for PTSD by a maladaptive learning pathway to fear response through a hypersensitive, hyperreactive, and hyperresponsive HPA axis [24].

Research carried out into post-traumatic stress disorder amongst soldiers involved in tours of duty in war zones shows that low cortisol levels may predispose individuals to PTSD: a good example of which may be the research into Swedish soldiers serving in Bosnia and Herzegovina with low pre-service salivary cortisol levels, who had a higher risk of reacting with PTSD symptoms, following war trauma, than soldiers with normal pre-service levels [25,26].

One can find within academic articles from the field of neurobiology research which suggests that people who suffer from PTSD have chronically low levels of serotonin, which contributes to the commonly associated behavioral symptoms such as anxiety, ruminations, irritability, aggression, suicidality, and impulsivity [25,26]. Serotonin also contributes to the stabilization of glucocorticoid production. Equally emphaised in these works is that an incorrect level of dopamine may explain many of the symptoms that we note in patients with PTSD. Low levels of dopamine can contribute to anhedonia, apathy, impaired attention, and motor deficits. Increased levels of dopamine can cause psychosis, agitation, and restlessness [27].

Olszewski and Varrasse [25] suggest that hyperresponsiveness in the norepinephrine system can be caused by continued exposure to high levels of stress. This is connected to the occurrence of flashbacks and nightmares frequently experienced by the patient with PTSD with an overactivation of norepinephrine receptors in the prefrontal cortex. A decrease in other norepinephrine functions (awareness of the current environment) prevents the memory mechanisms in the brain from processing that the experience, and emotions the person is experiencing during a flashback are not associated with the current environment.

It is worth emphasising that within neuro-academic circles there still exist an array of controversies and lively discussion as to the neurobiological basis of PTSD. For there has still not been shown an unequivocal direct link between cortisol levels and PTSD.

Yet one may conjecture, as Aardal-Eriksson et al. suggest [24], that the majority of reports indicate people with PTSD have elevated levels of the corticotropin-releasing hormone, lower basal cortisol levels, and enhanced negative feedback suppression of the HPA axis by dexamethasone [see also: 26,28].

For not without significance, as has been emphasised by Pąchalska, Kaczmarek and Kropotov [27], is the fact that the lengthy 'flooding' of the hippocampus neurons – simple in explanation for patients with PTSD, who have afterall often experienced extremely stressful situations, with hormones such as cortisol may result in the aforementioned changes in the brain structure (although this does not exclude the earlier mentioned certain neurobiological predisposition, which might equally have a significant influence on the appearance of PTSD within a given individual) [see also 26,27.28,29].

# MORPHOLOGICAL AND FUNCTIONAL RESEARCH INTO PATIENTS WITH PTSD

In recent years numerous articles have appeared devoted to the neuroimaging tests of patients with PTSD [28,29,30,3132,33,34] In this research the latest neurotechnologies are used allowing for the measurement of changes: (1). structural ones (e.g., TK, MRI) enabling for a depiction of the brain's structure, (2) hemodynamic ones, reflecting the neuron activity in actual time (e.g., positron emission tomography (PET), spectroscopy), as well as (3) electromagnetic

changes (magnetoencephalography (MEG) and QEEG and the potentials connected with an event, ERPs) allowing the measurement of neuron activity in milliseconds.

Neuroimaging studies in humans have revealed both morphological and functional aspects of PTSD [28,29]. There exists an injury relationship: the prefrontal cortex, amygdala, and hippocampus with PTSD. During high levels of stress the hippocampus, which is associated with the ability to place memories in the correct context of space and time, and with the ability to recall these memories, is suppressed. This suppression is hypothesized to be the cause of the flashbacks that often affect people with PTSD. When someone with PTSD undergoes stimuli similar to the traumatic event, the body perceives the event as occurring again because the memory was never properly recorded in the person's memory [29,30].

Of great significance in the understanding of PTSD are tests into the event related potentials (ERPs), which enable, among other things, the registering of brain functioning in a given situation – for example in the process of responding to presented stimuli, on a time scale of milliseconds [22,23]. The effect of this research is an attempt to explain PTSD by means of a model supposing that the significance of emotional memory is dependent on the amygdale. Adherents of the amygdalocentric model of PTSD state that the amygdala has been shown to be strongly involved in the formation of emotional memories, especially fear-related memories [28,29]. In addition they suggest that PTSD is associated with the hyperarousal of the amygdala and insufficient top-down control by the medial prefrontal cortex and the hippocampus in particular during extinction [31,33]

Kropotov [28,29], on the basis of many years of ERPs research, claims that the asolateral nucleus (BLA) of the amygdala is responsible for the comparison and development of associations between unconditioned and conditioned responses to stimuli, which results in the fear conditioning present in PTSD. According to him the BLA activates the central nucleus (CeA) of the amygdala, which elaborates the fear response. Descending inhibitory inputs from the medial prefrontal cortex (mPFC) regulate the transmission from the BLA to the CeA, which is hypothesized to play a role in the extinction of conditioned fear responses.

Many authors working on the basis of morphological and functional brain tests emphasise that in individuals with PTSD there may be observed disturbances in the functioning of several areas of the limbic system regulating emotions and memory as well as of the environs of the cortex functionally and anatomically connected to these areas. These involve the destabilisation of the networks of connections responsible for the correct course of cognitive functions (with special consideration for memory), emotional function and behaviour as well as the forming of the axical symptom of PTSD – flashbacks [29,30,31,32,33].

The aim of our research was a closer acquaintance with the mechanisms of PTSD thanks to the presentation of a patient case study, in whom PTSD had developed severly, and from whom event related potentials (ERPs) were tested.

# CASE STUDY

The patient, a 57-year-old man, a retired Polish Army lieutenant colonel, in whom a strong case of PTSD had been diagnosed. Following the attack on the World Trade Center, he saw two tours of duty at a military mission in Lebanon. He worked as an assistant commander of a field hospital for six months and was exposed to severe traumatic experiences amd the helplessness connected with these. As an example he evacuated patients during an explosion, he witnessed the death and mutilated body of his friend, as well as the deaths of several colleagues. He was slightly injured in the head during a dangerous exchange of fire: a fragment of glass injured his head. He did not lose consciousness and the wound was stitched, leaving a small scar on the scalp. However there occurred in him symptoms which appear in Mild Traumatic Brain Injury, such as: headache, dizziness, nausea/vomiting, trouble concentrating, memory problems, irritability, fatigue, ringing in the ears and sensitivity to noise and light. These symptoms, after around a year, almost completely disappeared. However, after several years the patient's condition started to drastically deteriorate and there appeared disturbances in both psychic and psychophysical functioning, which were classified as PTSD. Since 2010 he has been retired, although he continues to be treated psychiatrically and neurologically.

Ascertained during a comprehensive clinical diagnosis was the presence of post-traumatic stree disorder in accordance with the DSM 5 criteria (cf. Tab. 1).

MR tests confirmed the cerebral-sub-cortical dystrophy. One may conjecture that this is connected to the injury sustained. These are changes which may moderate the PTSD imaging as a result of the overlapping of symptoms [30,33].

On MR images brain parenchymal atrophy was prominent in the regions of the right medial prefrontal cortex, right hippocampus and right amygdala. In the right temporal lobe also postraumatic gliosis was visible.

Two areas of the brain have been identified as altered in PTSD: amygdala and hyppocampus. Combat veterans of the Vietnam war with PTSD showed a 20% reduction in the volume of their hyppocampus compared with veterans who suffered no such symptoms. The hyppocampus is associated with the ability to plays memories in the correct contest of space and time, and with the ability to recall the memory; during high stress times its activity in suppressed. This suppression in hypothesized to be the cause of the flashbacks that often plaugue PTSD patientts. Amygdala has been shown to be strongly involved in the formation of emotional fear-related memories; in PTSD it is associated with hyperarousal [27].

Also conducted was a series of tests allowing for the elimination of the spectrum of schizophrenia and other psychotic disturbances, obsessive compulsive disorder for intrusive thoughts that are recurring but not related to a specific traumatic event and malingering. The patient remains in retirement and there is no problem with financial and/or legal advantage. Equally the patient does not fulfil the criteria for dementia syndromes (VAD, FTD, Alzheimer) on the basis of DSM5.

Table 1. The criteria (categories) and DSM 5
Diagnostic criteria 309.81 (F43.10).

| Code | Criteria (categories) and symptoms of PTSD according to DSM-5 | Description of the symptoms of PTSD in the given patient |
|---|---|---|
| **A** | **Exposure to actual or threatened death, serious injury, or sexual violence in one (or more) of the following ways:** | |
| A1 | Directly experiencing the traumatic event(s). | Exposure to threatened death. In one of the shooting incidences he was wounded in the head by a piece of glass from a car window. Mild TBI appeared. |
| A2 | **Witnessing, in person, the event(s) as it occurred to others.** | Witnessing of the actual death of his dear friend and the deaths of a few colleagues. |
| A3 | Learning that the traumatic event(s) occurred to a close family member or close friend. In cases of actual or threatened death of a family member or friend, the event(s) must have been violent or accidental. | Learning that the traumatic events occurred to result in actual violent death and also threatened the death of few colleagues. |
| A4 | Experiencing repeated or extreme exposure to aversive details of the traumatic event(s) (e.g., first responders collecting human remains: police officers repeatedly exposed to details of child abuse). | Experiencing extreme exposure to aversive details of the traumatic event (first responders collecting the human remains of his dear friend). |
| **B** | **Presence of one (or more) of the following intrusion symptoms associated with the traumatic event(s), beginning after the traumatic event(s) occurred:** | |
| B1 | Recurrent, involuntary, and intrusive distressing memories of the traumatic event(s). | Recurrent daily presence of involuntary, and intrusive distressing memories |
| B2 | Recurrent distressing dreams in which the content and/or affect of the dream are related to the traumatic event(s). | Recurrent (almost every night) distressing dreams in which the content and sometimes the effect of the dream are related to the traumatic events. |
| B3 | Dissociative reactions (e.g., flashbacks) in which the individual feels or acts as if the traumatic event(s) were recurring. (Such reactions may occur on a continuum, with the most extreme expression being a complete loss of awareness of present surroundings. | Flashbacks in which he feels or acts as if the traumatic event(s) occur on a continuum, with the most extreme expression being almost a complete loss of awareness of his present surroundings. |
| B4 | Intense or prolonged psychological distress at exposure to internal or external cues that symbolize or resemble an aspect of the traumatic event(s). | None |
| B5 | Marked physiological reactions to internal or external cues that symbolize or resemble an aspect of the traumatic event(s). | None |
| **C** | **Persistent avoidance of stimuli associated with the traumatic event(s), beginning after the traumatic event(s) occurred, as evidenced by one or both of the following:** | |
| C1 | Avoidance of or efforts to avoid distressing memories, thoughts, or feelings about or closely associated with the traumatic event(s). | Avoid distressing memories about the traumatic event(s). |
| C2 | Avoidance of or efforts to avoid external reminders (people, places, conversations, activities, objects, situations) that arouse distressing memories, thoughts, or feelings about or closely associated with the traumatic event(s). | Avoid external reminders (conversations and objects) that arouse distressing memories about the traumatic event(s). |
| **D** | **Negative alterations in cognitions and mood associated with the traumatic event(s), beginning or worsening after the traumatic event(s) occurred, as evidenced by two (or more) of the following:** | |
| D1 | **Inability to remember an important aspect of the traumatic event(s) (typically due to dissociative amnesia and not to other factors such as head injury, alcohol, or drugs).** | Inability to remember an important aspect of the traumatic event(s) (due to dissociative amnesia). |

| | | |
|---|---|---|
| D2 | Persistent and exaggerated negative beliefs or expectations about oneself, others, or the world (e.g., "I am bad," "No one can be trusted," 'The world is completely dangerous," "My whole nervous system is permanently ruined"). | Persistent and exaggerated negative beliefs or expectations about oneself, and the world: often claimed that "Man can't do anything;" "Various things happen in life." |
| D3 | Persistent, distorted cognitions about the cause or consequences of the traumatic event(s) that lead the individual to blame himself/herself or others. | Persistent, distorted cognitions about the consequences of the traumatic event(s) that lead the individual to blame himself or others. |
| D4 | Persistent negative emotional state (e.g., fear, horror, anger, guilt, or shame). | Persistent negative emotional state (anger and less frequently fear). |
| D5 | Markedly diminished interest or participation in significant activities. | He doesn't participate in significant activities at all. |
| D6 | Feelings of detachment or estrangement from others. | Feelings of detachment from others. |
| D7 | Persistent inability to experience positive emotions (e.g., inability to experience happiness, satisfaction, or loving feelings). | Persistent inability to experience happiness, satisfaction, or love to his closest family. |
| **E** | **Marked alterations in arousal and reactivity associated with the traumatic event(s), beginning or worsening after the traumatic event(s) occurred, as evidenced by two (or more) of the following:** | |
| E1 | Irritable behavior and angry outbursts (with little or no provocation) typically expressed as verbal or physical aggression toward people or objects. | Irritable behavior and angry outbursts (with no provocation) typically expressed as verbal aggression toward people. |
| E2 | Reckless or self-destructive behavior. | None |
| E3 | Hypervigilance. | Hypervigilance, mainly during the day. |
| E4 | Exaggerated startle response. | None |
| E5 | Problems with concentration. | He is not able to concentrate on the topic of conversation or during a long task. |
| E6 | Sleep disturbance (e.g., difficulty falling or staying asleep or restless sleep). | Sleep disturbance (difficulty falling asleep and restless sleep). |
| **F** | **Duration of the disturbance (Criteria B, C, D, and E) is more than 1 month.** | Duration of the disturbance (Criteria B, C, D, and E) is more than 1 year. |
| **G** | **The disturbance causes clinically significant distress or impairment in social, occupational, or other important areas of functioning.** | The disturbance causes clinically significant distress and impairment in social areas of functioning. |
| **H** | **The disturbance is not attributable to the physiological effects of a substance (e.g., medication, alcohol) or another medical condition.** | The disturbance is not attributable to the physiological effects of a medication or alcohol). |
| **With dissociative symptoms:** | **Depersonalization: Persistent or recurrent experiences of feeling detached from, and as if one were an outside observer of, one's mental processes or body (e.g., feeling as though one were in a dream; feeling a sense of unreality of one's self or body or of time moving slowly).** | None |
| | **Derealization: Persistent or recurrent experiences of unreality of one's surroundings (e.g., the world around the individual is experienced as unreal, dreamlike, distant, or distorted).** | He feels recurrent experiences of unreality of surroundings: the world around is experienced as unreal and distant. |

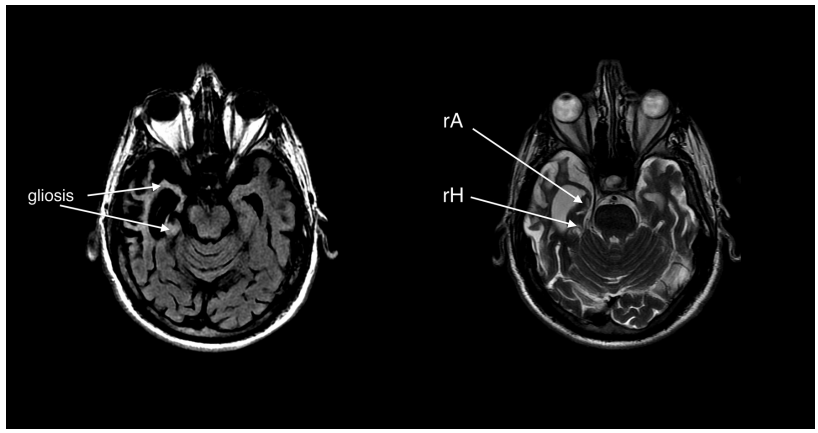


Fig. 1. Brain MRI, a. FLAIR T2 sequence, axial plane: hiperintensitivity of the brain tissue- signs of gliosis (arrow), b. frFSET2 sequence, axial plane: predominant atrophy of the right Hyppocampus (rH arrow) and right Amygdala (rA arrow)

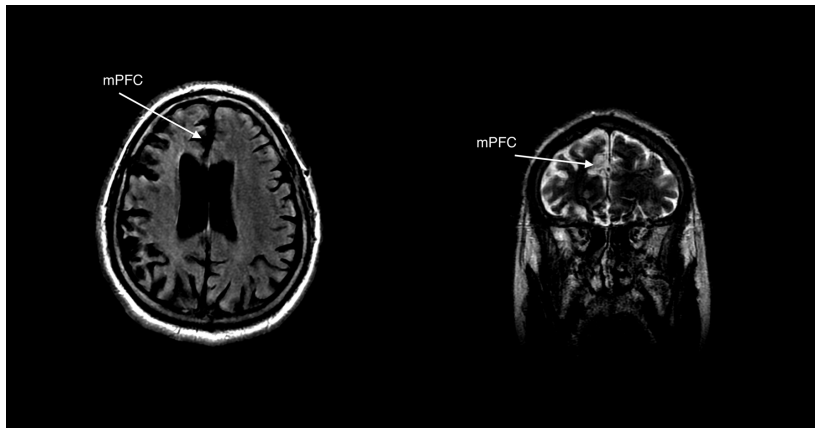


Fig. 2. Brain MRI. a. FLAIR T2 sequence: axial plane: predominant atrophy of the right medial prefrontal cortex (mPFC arrow). b. frFSET2 sequence, coronal plane: predominant atrophy of the right medial prefrontal cortex (mPFC arrow)

The patient's wife claims that he has serious problems with falling asleep and staying asleep. His sleep, despite the taking of sleeping tablets, is too short and light. He awakes several times in the night and shouts out or gives accounts of various nightmares. The content of these suggests that sometimes these are nightmares in the form of dreams though most frequently these are flashbacks. There has also occurred a change in the manner by which he expresses emotion. Before the illness he had been a warm, nice and sincere individual in social contact. For the last three years he has become an emotionally cold person one unable to express his feelings either in relation to his wife or family. He lacks any will to do anything either at home or outside it. His behaviour means that he is isolated from society. This state of affairs may be defined as 'social death.'

As a result of these symptoms he wife undertook the decision to have him treated. Since June 2015 he has participated in individual cognitive, behavioural and psycho therapy. Despite all of this his health continually deteriorates.

### Neuropsychological tests

Neuropsychological tests were conducted twice: before the commencement of therapy in June 2015 (Test 1) as well as half a year later i.e., in December 2015 (Test 2). While these tests were being conducted the patient displayed anxiety. Following the end of even the smallest little sub-test he would ask if it was the end of proceedings. In addition there was observed smaller or greater anxiety attacks (connected with the fact that his wife was not participating in the testing or that he had forgotten his coat), panic attacks (chiefly connected with intrusive recollections and/or flashbacks). Asked what it is that he sees he fails to reply, extremely rarely does he talk about a traumatic situation (reproducing rather elements of the situation rather than its entirety) and he talks chaotically about events from conflict situations in various parts of the world. A confrontation of these accounts with the information possessed by his wife allows one to talk of florid confabulations. In moments of the greatest disturbance he will look for some object or other and when he has found it he will manipulate it in a compulsive way (e.g., he would turn the clock hands trying to set the date at the 17$^{th}$ of December 2015, and when another date was shown he would start to turn the winder again from the beginning going through the subsequent days of the month several times) until the desired effect was achieved. Then he calms down and may be examined further. After every instruction given he will repeat the statement 'I have remembered it and will carry it out.'

Table 2. presents the results of the neuropsychological tests. In Test 1 the appearance of disturbances in cognitive and exectutive functions was confirmed. Of especial note are the results obtained in the Wechsler Memory Test – III (WMS-III) in which marked disturbances in selectivity and attention concentration, the dynamism of working memory and logical and verbal memory were observed both in the testing directly after the presentation of material for memorisation as equally after a 30-minute adjournment. This means that the patient is unable to learn new material [cf. also 35]. In addition there were noted marked disturbances in the executive functions. In Test 2, conducted after a half-year of treatment and psychotherapy, the results of the neuropsychological tests not only failed to improve but in point of fact deteriorated significantly. The patient in practice was unable to do any test task for almost the entirety of the tested neuropsychological parameters. **This fact meant cognitive control underwent a marked deterioration**.

In connection with the changes observed in MRI as well as the complaints of the family over increasing impulsiveness, aggression and nocturia, the patient was tested by means of the Frontal Behavioural Inventory [36,37]. This inventory, in its authorised Polish version, comprises 24 questions enabling one to evaluate disturbances in social behaviour. It encompasses also an evaluation of motor

Table 2. The results of neuropsychological testing in Test 1 and 2.

| Method | Test 1 | Test 2 |
|---|---|---|
| **WAIS-R** | | |
| **I.I.** – total | 93.5/100 | execution interrupted |
| **I.I.** – verbal | 98.5/100 | execution interrupted |
| **I.I.** – non-verbal | 87.5/100 | execution interrupted |
| **WMS – III** | | |
| **Subtest of attention** | | |
| WMS-**III** spatial subtest | 12 (75th%) | execution interrupted |
| **sight-spatial tests** | | |
| WAIS-**III** building blocks subtest | 8 (25th%) | execution interrupted |
| **Logical memory** | | |
| WMS-**III** logical memory (direct) | 11/24 | execution interrupted |
| WMS-**III** logical memory (with a 30-minute delay) | 8/24 | execution interrupted |
| WMS-**III** sight reconstruction (direct) | 12/41 | execution interrupted |
| WMS-**III** sight reconstruction (with a 30-minute delay) | 6/41 | execution interrupted |
| **Verbal memory** | | |
| CVLT reconstruction after a short break | 2/9 (<1st%) | 0/9 (<1st%) |
| CVLT reconstruction after a long break | 2/9 (<1st%) | execution interrupted |
| CVLT reconstruction after a long break with a clue/prompt | 2/9 (<1st%) | execution interrupted |
| **EXECUTIVE FUNCTIONS** | | |
| **Trail Marking Test (TMT)*** | | |
| number sequences | 150 seq. (<1st%) | execution interrupted |
| number and letter sequences | 150 seq. (<1st%) | execution interrupted |
| **Test Interferencji STROOP'A** | | |
| Colours | 41 seq. (16th%) | execution interrupted |
| Words | 42 seq. (63rd%) | execution interrupted |
| interference | 128 seq. (<1th%) | execution interrupted |
| **Wisconsin Card Sorting Test [WCST]** | | |
| Categories | 2 (>16th%) | execution interrupted |
| perserveration errors | 19 (37th%) | execution interrupted |
| errors in classification | 63 (<19th%) | execution interrupted |
| errors in the transfer to particular categories | execution interrupted | execution interrupted |

***TMT- Trail Marking Test**
Level of execution (in seq.) corresponds with percentiles:
98-99% – very high,
91-97% – high,
75-90% – averagely high,
25-74% – average,
9-24% – low average,
3-8% – on the border with low,
2% and lower – weak.

capabilities, linguistic abilities as well as alien hand syndrome. A four-degree scale is used in the evaluation of results:
0 – an absence in the appearance of behavioural disturbances,
1 – mild disturbance or its periodic appearance,
2 – moderate disturbances,
3 – serious disturbances, maintained almost all the time.

The inventory was completed by the patient's wife. The questions were grouped in accordance with the test authors' suggestion, meaning:

1. ***Negative behaviour disturbances*** e.g.: apathy, aspontaneity, indifference, thought rigidity, clarity, personal neglect, proneness to be distracted, lack of attention, loss of insight, logopedia, verbal apraxia and alien hand syndrome.
2. ***Positive behaviour disturbances*** e.g.: perservations, sensitivity, jokiness, unpredictability, irresponsibility, inappropriateness, impulsiveness, euphoric anxiety, aggression, hyperorality, hypersexuality, as well as non-retention of urine, affected lack of restraint.

The patient may be awarded, for the results obtained across the entire inventory, a minimum of 0 points, with a maximum score of 72. The cut off point at which there appear the traits of frontal lobe syndrome is 26.6 pts.

A comparison of the results obtained in Test 1 and Test 2 in the **FBInv** inventory shows an increase in the features of frontal lobe syndrome in the area of co-called **positive behaviour disturbances, except perseverations, irritability and hypersexuality** (cf. Fig. 3).

Yet the results obtained during Test 1 were below the so-called cut-off line, which means that frontal lobe syndrome did not occur. While in Test 2 the symptoms of aggressiveness, impulsiveness and anxiety increased. There was noted an enforcement in irrational and inappropriate behaviour. The patient almost lost compleley his ability for emotional control. In addition problems with urine retention appeared. The results obtained exceeded the so-called cut off point and formulated mild frontal lobe syndrome. These features overlap into PTSD.

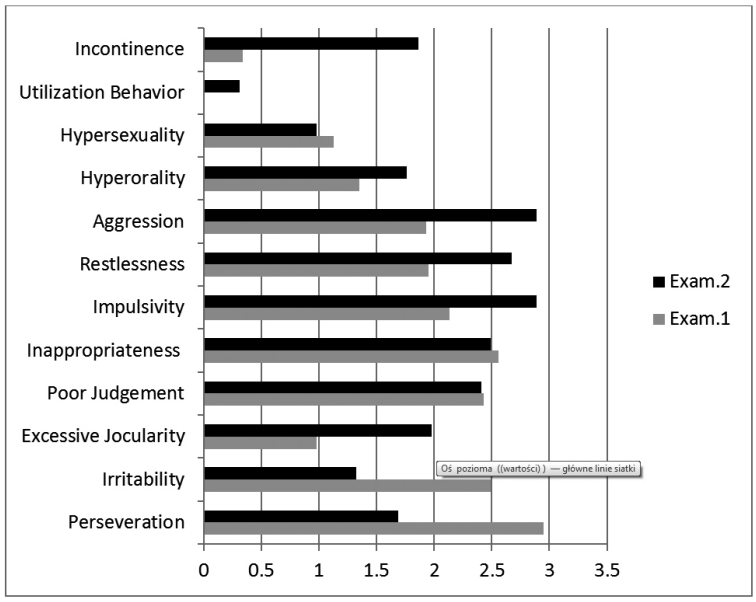


Fig. 3. Results obtained by the patient in Test 1 and 2 in relation to behaviour disturbances in the FB Inventory

## Neurophysiological testing

### Event Related Potentials, (ERPs)

A. Event related potentials, (ERPs) were utilised in the patient to evaluate the functional state of the brain to uncover the PTSD neuromarker [27,28,29]. This approach was adopted for a number of reasons:
   1. ERPs have the highest level of definition (resolution) in time (on a scale of micro seconds) when compared to other methods of imaging such as in fMRI or PET (which have a resolution of 6 seconds and higher) [27].
   2. ERPs are an important tool allowing for the discovery of PTSD neuromarkers
   3. They enable the discovery of p neuromarker PTSD [29].
   4. As opposed to the measurement of the spontaneous oscillation EEG, ERP reflect the stages of information flow in the brain [27,28,29, 38,39,40]. The diagnostic strength of ERP was also enhanced by the recent appearance of new analytical methods; such as (Independent Component Analysis, ICA) and Low Resolution Electromagnetic Tomography (sLORETA) [27, 28,29,41].

The research employed a modified paradigm of two virtual stimulants GO / NO GO (Fig. 4). Three categories of visual stimuli were chosen:

- 20 various animal photos, referred to as 'A;'
- 20 various plant photos, referred to as 'P;'
- 20 different photos of various professions/occupations, presented together with a 'new' artificial sound, referred to as H + Sound.'

All the visual stimuli were chosen so that they had a similar magnitude and clarity. Randomly the 'new' sounds composed of five 20-ms fragments were loaded with tones of various frequencies (500, 1000, 1500, 2000 and 2500 Hz). A new combination of sounds was used every time, whereby new sounds appeared unexpectedly (the likelihood of their occurrence being 12.5%).

Four categories of stimuli were used (see Fig. 4): A-A, A-P, P-P i P - (H + sound). The attempts were divided into four blocks, after one hundred attempts for each of the blocks. In each block a unique set of five A stimuli were chosen, five B, and 5 H stimuli. The patient practiced the tasks before the actual commencement of the recording itself.

During the test itself the patient sat up straight in an armchair, looking towards the computer screen. His task was to click the right-hand side of the mouse in response to all the AA pairs as quickly as at all possible and to refrain from clicking on seeing other pairs: A-P, P-P, P- (H + sound).

In accordance with the test design two preparatory sets were distinguished: the 'continuation' set, in which the stimulus A is presented as the first stimulus when the patient will have prepared for the answer; and the 'discontinuation' set wherein the stimulus P is presented as the first, yet the patient will not have to prepare to answer. In the 'continuation' set the pairs A-A are deemed as 'GO' attempts, while the pairs A-P as 'NOGO' attempts.

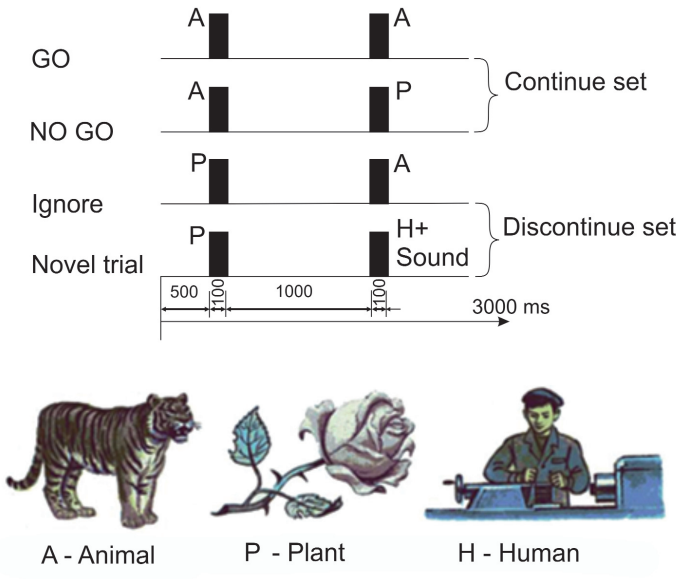


Fig. 4. The schemati presentation of two stimuli in GO / NOGO tasks. From top to bottom: the temporal dynamic of stimuli in four trail categories: abbreviations: A (Animals), P (Plant), H (Human) represent the respective categories. The GO attempts occur when the stimuli A-A require from the patient the pressing of the button. The NOGO attempts signify the stimuli representing animals and plants (A-P), which require the patient to retrain from the prepared action. The attempts GO and NOGO represent the set 'continuing' the test in which patients have to prepare themselves for action after the first appearance of the stimulus (A). Attempts of the 'Ignore' type refer to stimuli presenting plants (P) which do not require preparation for action. Attempts of the 'New' type are pairs that do not require any action whatsoever, with the presentation of the 'new' sound as a second stimulus. Attempts of the 'Ignore' and 'New' test type constitute 'discontinuation' sets, in which the patient does not have to undertake any preparation following the first stimuli of the presentation. The temporal divisions are presented at the bottom of the picture. The attempts are comprised of a pair of stimuli at 1 second intervals. The time for the stimuli is 100 ms

EEG was registered from 19 points on the patient's scalp. The electrodes were placed in accordance with the International 10-20 System. The referential electrodes were attached to the ear. In the result analysis the mean for latency in replies and the variations in replies between tests was calculated. Equally calculated was the omission bias (a lack of GO reactions) and errors in a failure to refrain (the absence of restraint in the NOGO reaction).

# BEHAVIOURAL DATA

The QEEG and ERPs tests were conducted on 07/11/2015. In Tab. 3. are to be found the behavioural data from the visual control task completion [(Visual Control PsyTask, VCPT 1-GRAV 56-60 [28].

Analysis of the data generated confirmed the ascertainment that the patient in practice was unable to deal with task completion during the course of the PsyTask test (cf. Fig. 5).

Tab. 3. Behavioural data from the visual control task completion [(Visual Control PsyTask, VCPT 1-GRAV 56-60 (38)]

| Group name | Total | Averaged | Error | Omisson | Comission | Artefact | RT1 | RT2 | var(RT1) | var(RT2) |
|---|---|---|---|---|---|---|---|---|---|---|
| a-a GO [D] | 100 | 14 | 0.00% | p=0.000 | p=0.816 | 14 | p=0.001 | 0 | p=0.000 | 0.0 |
| a-p NoGO [D] | 100 | 34 | 0.00% | 0.00% | p=0.000 | 42 | 0 | 0 | 0.0 | 0.0 |
| p-p [D] | 100 | 27 | 0.00% | 0.00% | p=0.000 | 49 | 0 | 0 | 0.0 | 0.0 |
| p-h [D] | 100 | 37 | 0.00% | 0.00% | p=0.000 | 48 | 0 | 0 | 0.0 | 0.0 |
| + [D] | 200 | 93 | 0.00% | 0.00% | 0.00% | 107 | 0 | 0 | 0.0 | 0.0 |
| - [D] | 200 | 77 | 0.00% | 0.00% | 0.00% | 123 | 0 | 0 | 0.0 | 0.0 |
| a-p NoGO - a-a GO [D] | 0 | 48 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| p-h - p-p [D] | 0 | 64 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| - - + [D] | 0 | 170 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| a-a GO [1] | 100 | 14 | 0.00% | 72.00% | 0.00% | 14 | 716 | 0 | 42.6 | 0.0 |
| a-p NoGO [1] | 100 | 34 | 0.00% | 0.00% | 24.00% | 42 | 0 | 0 | 0.0 | 0.0 |
| p-p [1] | 100 | 27 | 0.00% | 0.00% | 24.00% | 49 | 0 | 0 | 0.0 | 0.0 |
| p-h [1] | 100 | 37 | 0.00% | 0.00% | 15.00% | 48 | 0 | 0 | 0.0 | 0.0 |
| + [1] | 200 | 93 | 0.00% | 0.00% | 0.00% | 107 | 0 | 0 | 0.0 | 0.0 |
| - [1] | 200 | 77 | 0.00% | 0.00% | 0.00% | 123 | 0 | 0 | 0.0 | 0.0 |
| a-p NoGO - a-a GO [1] | 0 | 48 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| p-h - p-p [1] | 0 | 64 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| - - + [1] | 0 | 170 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| a-a GO [2] | 100 | 14 | 0.00% | 3.62% | 0.05% | 14 | 398 | 0 | 7.4 | 0.0 |
| a-p NoGO [2] | 100 | 34 | 0.00% | 0.00% | 1.21% | 42 | 0 | 0 | 0.0 | 0.0 |
| p-p [2] | 100 | 27 | 0.00% | 0.00% | 0.13% | 49 | 0 | 0 | 0.0 | 0.0 |
| p-h [2] | 100 | 37 | 0.00% | 0.00% | 0.08% | 48 | 0 | 0 | 0.0 | 0.0 |
| + [2] | 200 | 93 | 0.00% | 0.00% | 0.00% | 107 | 0 | 0 | 0.0 | 0.0 |
| - [2] | 200 | 77 | 0.00% | 0.00% | 0.00% | 123 | 0 | 0 | 0.0 | 0.0 |
| a-p NoGO - a-a GO [2] | 0 | 48 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| p-h - p-p [2] | 0 | 64 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |
| - - + [2] | 0 | 170 | 0.00% | 0.00% | 0.00% | 0 | 0 | 0 | 0.0 | 0.0 |

**Symbol markings:**
a-a GO (animal – animal) = GO
a-p NOGO [D] (animal – plant) = NOGO
p-p [D] (plant – plant) = Ignore
p-h [D] (plant – human) Ignore

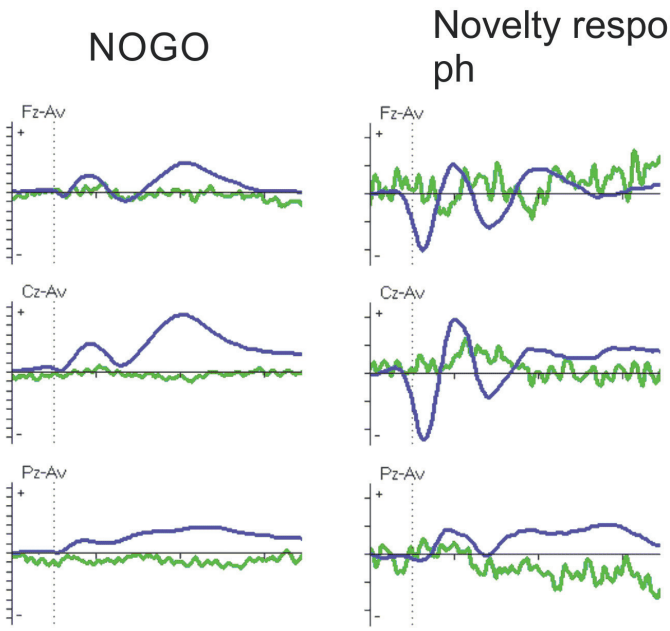


Fig. 5. ERPs registered as a response to visual stimuli. P3 NOGO on the left side and P3 registered for new stimuli in the right. The interrelation of the U curve after task completion is reversely proportional to the cortex activity. The vertical axis is task realisation while the horizontal axis is brain activation. Of note is the fact that there is an absence of alpha activity in the brain.Explanation: Green = the patient; Dark blue = healthy individuals [referential data from the data bases at the Human Brain Institute, (HBI in Switzerland)

Of especial note is the fact that the EEG spectra can be evaluated with great difficulty for there occurred in the patient a low-voltager subtype of rapid EEG. In the testing of the event related potentials (ERPs) it was possible to identify only a few replies, for the patient's cortex is burdened and the brain almost does not react not only to standard stimuli but even to new stimuli. Behaviour observation during the time of task completion allows one to state that the patient was disturbed during the entire duration of the testing and there occurred from him on several occasions chaotic utterances which point strongly to the presence of a deep level of anxiety. Despite the fact that he understood the task he would often, when he saw two animals on the monitor screen, click on both sides of the mouse or would hold down the click for far too long registering with the said 'I have remembered the task and completed it.' These facts meant that there appeared many artefacts in the EEG record.

In order to help the patient overcome the problems that had occurred within him, recommended was a calming of the brain through the use of programmes designed to relax the body (e.g., classical massage) as well as neurofeedback directed towards reducing the high beta.

# DISCUSSION

The patient, a 57-year-old, retired Polish Army lieutenant colonel, who had seen active service twice in Lebanon, was diagnosed with Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder, in accordance with the DSM 5 criteria. The neuropsychological tests confirmed an increasing degree of disturbance within cognitive and emotional processes as well as behavioural disturbances. He almost lost cognitive and emotional control. The factors conducive to such an accentuation in the symptoms were structural and functional changes in the brain (cerebral-sub-cortical dystrophy as well as destabilisation in the connections between these structures) as well as the appearance of a rare low-voltage subtype of rapid EEG. It is worth emphasising that individuals with such an EEG subtype should never really be sent on difficult military missions, for in accordance with the present state of knowledge it is much easier for there to develop within them fear/anxiety as a state of being and the varied psychic disturbances related to this, including the development of PTSD [27,28].

The neuropsychological and neurophysiological tests conducted including neuroimaging of the functions of the brain by the method of MR, QEEG and ERPs, have shown how important a reliable differential diagnosis based on evidence based medicine is as well as on personal medicine. They allow one to understand the essences of the mechanism which lies at the core of the disturbances appearing in the patient under observation. There was no reaction in the cognitive tasks of the structures of the anterior cingulated cortex, which are involved in the tranferance of information in the functional loops – particularly the frontal lobal: cerebral-sub cortical – as well as in the process of arousing other cerebral areas, and in particular the frontal planes [43,43]. The frontal planes are characterised by a markedly reduced ability to monitor activities, including a lack of control and retraint in stimulations stemming from the sub-cortical parts of the brain to the cortex. A weakening in the functioning of these structures and the functional loops **results in a loss in cortical control over the sub-cortical structures connected with emotional processes and memory**. As a result of this emotional processes dominate over cognitive processes and in this situation the patient's brain is not able, for example, to reconstruct events in serial order [43], which means as a consequence that the patient's utterances are chaotic. And in addition he does not even really react to new stimuli and consequently does not remember new events and information. Therefore he constantly reconstructs intrusive recollections of traumas, which circulate in the buffer working memory.

The disturbances occurring in our patient may explain the model of restraint in cortex activity connected with the impulses flowing from the sub-cortical structures (Fig. 6). When there occurs a loss in cerebral-subcortical structures and the destabilisation of neuron connections between these structures associated with this (as is the case in the patient examined by us) there occurs a desynchronisation of activation within the central sulcus [28,45].

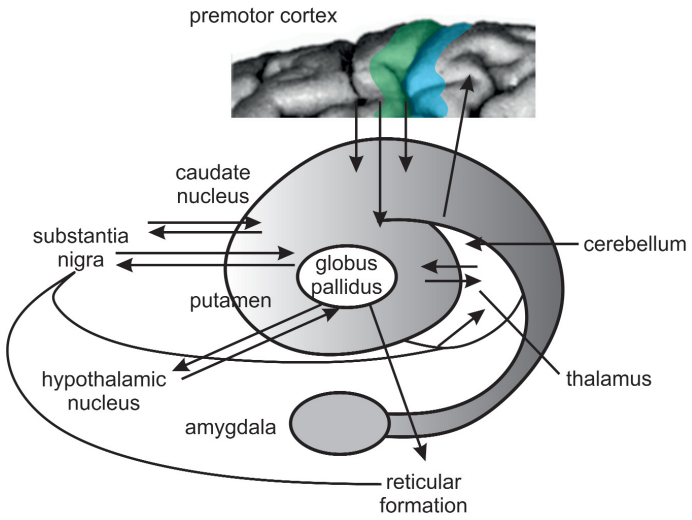


Fig. 6. Model of restraint in cortex activity connected with the impulses flowing from the sub-cortical structures.

As a consequence of such a structural and functional organisation it is easy to understand the wealth of clinical symptoms occurring in the patient, with particular consideration being given to cognitive, emotional disturbances and disturbances in behaviour (cf. Fig. 7).

It is worth adding that as a result of the joint occurrence of symptoms of frontal lobe syndrome with those of PTSD the patient lost not only cognitive control but also emotional control something equally observed by Hannah et al. [45] in diagnosing similar cases. He is unable to control his experiences, or the intrusive recollections of trauma, he is unable to critically tackle and work on those negative emotional reactions occurring in him. First and foremost he possesses a limited sense of reflection on events, he is unable to distance himself from these

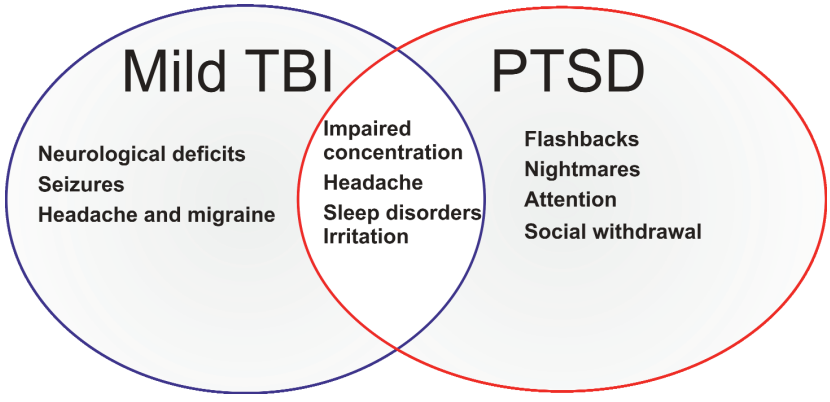


Fig. 7. Mild Traumatic Brain Injury (TBI) with symptoms of PTSD

incidents and with the same return to a state of 'normal' functioning. In this way thanks to the constant maintaining of stimulations within the discussed connections loop the events to some extent have been build permenantly into his perception of reality and experience of emotion [46].

**In summing up** it follows to emphasise that our application of new neurotechnologies in the diagnosis of the patient's brain functioning as well as the close cooperation of a neurologist, neuropsychologist and neurophysiologist turned out to be highly useful in understanding the mechanisms lying at the basis of the **joint occurrence of** Mild Traumatic Brain Injury/ PTSD [45,46].

The results obtained are invaluable from the cognitive point of view for they explain why psychosocial events may generate certain changes in the functional structure of the brain. If there occurs an additional factor in the form of Mild Traumatic Brain Injury these changes may be large and the patient may lose their ability for cognitive and emotional control, as was the case with our patient. A favourable factor may be the appearance of rare, low-voltage rapid EEG (Kropotov 2009). These have equally a practical significance, confirming:

The purposefulness of differential diagnostics through the use of new neurotechnologies, including ERPs, which lead to a better understanding of the mechanisms of the symptoms of Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder, and therefore to the development of more effective programmes of therapy for soldiers taking part in armed conflicts, in whom the mentioned disturbances have occurred.

The necessity to test soldiers sent on difficult military missions through the help of QEEG/ ERPs methodology allowing to screen out individuals with the above mentioned EEG profile.

This would reduce what is already an excessively large number of cases of PTSD in soldiers taking part in armed conflicts and in difficult military missions.

# CONCLUSIONS

The carrying out on the patient of ERPs made it possible to understand the brain mechanisms lying at the basis of the overlapping symptoms of Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder. The appearance of low-voltage, rapid EEG may possibly be a factor favouring the development of PTSD, particularly in patients who have experienced Mild Traumatic Brain Injury. The results obtained illustrate the need to exclude/eradicate low-voltage EEG in soldiers despatched to conflict regions.

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