Visceral theory of mental disorders

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Abstract

Based on the visceral theory of sleep by I. N. Pigarev, we hypothesize that mental illnesses are caused due to errors in the commutation of external and internal information flows in the brain. As a consequence of these errors, visceral information is constantly present in the cerebral cortex and during wakefulness, on the one hand, is misinterpreted as coming from the outside world, and on the other hand creates a persistent noise overload in exteroceptive (visual and auditory) and proprioceptive channels leading in a long run to the over-strain and malfunction of the adaptive mechanisms of the brain.

1. Introduction — the birth of the idea

It so happened that we had a misfortune to observe for years a struggle of our close friend with bipolar disorder — a nasty mental illness characterized by alternating episodes of mania, hypo-mania and depression, intertwined with periods of remission [1, 2, 3].

Bipolar disorder affects more than one percent of the world’s population irrespective of nationality, ethnic origin, or social status, which is similar to that of schizophrenia — another major psychiatric disorder [1, 2].

It is evident that when people have a mental illness, their brain works differently from the usual way. However what exactly causes the illness is still unknown. The modern neurobiological evidence of functional and structural abnormalities, as well as gray-matter and white-matter changes related to the bipolar illness strengthen the view what seems to be clear from the very beginning: the bipolar disorder is a condition in which emotions gain too
much power over behavior \[4, 5\]. At that it is impossible to indicate a single genetic or neurobiological cause of the disease. Diverse biological factors can lead to abnormalities in signal transduction pathways and, as a result, to dysfunction of interconnected brain networks, which reveals itself as bipolar disorder. It seems two interrelated prefrontal-limbic networks play a crucial role in the pathophysiology of bipolar illness. The first network, commonly referred to as the Automatic/Internal emotional regulatory network, modulates amygdala responses to endogenously generated feeling states, induced by memories of past. The second network, commonly referred to as the Volitional/External regulatory network, modulates voluntary regulation of externally induced emotional states and suppresses maladaptive affects \[4\]. However it is not altogether clear why these interconnected brain networks become deteriorated and desynchronized during development of the illness.

In our case one circumstance struck us as a surprising peculiarity. All episodes of the illness were accompanied by a distinguished psychosomatic symptom. At the beginning of each episode the body began to become more and more covered with red spots as from a bite of mosquitoes or midges and then remained in this state until the end of the episode. Rationalization of this condition was also invariably the same that she was heavily bitten by mosquitoes in the childhood and now it all comes out. Besides, as a child, she was forced by her mother to collect shards of broken glass with her bare hands when she accidentally broke a glass and some splinters remained in the skin. That’s why she’s digging them now out from the skin.

Later we learned that obsessive-compulsive symptoms, such as picking at skin (excoriation), are common in patients with bipolar disorders \[6\]. There is continuing debate about whether obsessive-compulsive disorder and bipolar disorder are just comorbid two independent conditions or the first is a specific subtype of the second \[6\]. In our case the association between the two conditions was so persistence and striking that we had a growing feeling that if we understand the cause of this psychosomatic syndrome we understand the cause of the bipolar disorder.

There are indications that inflammation is increased in the periphery of the body during both manic and depressive episodes of the bipolar disorder with some return to normality during remissions \[4, 7\]. It seems dysregulation of glial-neuronal interactions, and as a result over-activity of microglia — the brain’s primary immune elements, is a primary source of the inflammation \[4, 7\].

We see some similarity in inflammatory reaction on the spurious midge
bites and abnormal emotions without apparent external cause characteristic in bipolar disorder. Our hypothesis is that in both cases some internal (visceral) information is misinterpreted as coming from external sources.

Emotional experience is a result of integrating by brain internal and external information streams, the first coming from the internal bodily environment and the second — from sensory inputs from the outside world \[8, 9\]. Recent study \[10\] hints that brain uses the notorious principle divide and conquer to avoid sensory overload when presented with competing signals. It is not excluded that the ubiquitous presence of sleep or sleep-like states in all animals with brains, from worms to humans, indicates that the same principle underlines the brain’s information-processing architecture that copes with the internal and external information streams.

2. The visceral theory of sleep

Sleep is an universal and fundamental biological phenomenon in animal kingdom. However its genuine function remains one of the most persistent, enigmatic and perplexing mysteries in biology \[11\]. If sleep indeed plays a vital role, as every piece of evidence does indicate, a better understanding of its purpose is desired and such an understanding promises a great advance in biology and medicine.

The sleep-research pioneer Allen Rechtschaffen once noted that “if sleep does not serve an absolute vital function, then it is the biggest mistake the evolutionary process ever made” \[12\]. Although it was provocatively argued that sleep is indeed an evolutionary junkyard of non-adaptation and essentially has no other function than simple rest when animals have nothing else to do \[13\], such an attitude is unconvincing and does not withstand a close inspection \[14\]. There exist ample evidence for a functional role of sleep other than inactivity, indicating that sleep must serve a function so important that it outweighs evolutionary pressure due to the inherent danger that animals assume by sleeping \[14\].

The visceral theory of sleep, developed by I. N. Pigarev \[15, 16, 17, 18\], identifies the longed searched vital function of sleep: the same cortical neurons, which process exteroceptive information in wakefulness, during sleep switch to the processing of information coming from the various visceral systems.

Although at first sight this hypothesis seems paradoxical, it is in harmony with findings of computational science that the universal processors are much
more effective way to build a computer than development of processors specialized for a single function.

In visceral theory of sleep cerebral cortex plays a role of universal processor. Information streams in the brain during wakefulness and during sleep are schematically shown in Fig. 1. Of course, Fig. 1 conveys only the principal idea of the visceral theory of sleep that the processing of exteroceptive and interoceptive information streams are largely separated in time. The real architecture of gating elements that ensure such a separation is expected to be much more complex than shown in Fig. 1. For example, it is a well known fact that in conditions when it is necessary to remain awake in spite of high natural sleep pressure a local sleep develops in high order cortical areas. At that simple behavioral activities, which do not need engagement of the highest cortical resources, are still maintained even when part of the brain is sleeping [19]. It is evident that to ensure such a brain plasticity in information processing more complex gating system is needed than shown in Fig. 1. Nevertheless even this simplified picture does allow to explain a whole series of pathological phenomena related to the sleep-wake cycle that are caused by desynchronization of the switching of information streams in the brain [16].

Dreams constitute the most frequent and harmless pathology of sleep. According to the visceral theory of sleep, dreams happen during a brief transient period from wake to sleep or vice versa. For example, while going to sleep, if the gating to the consciousness block is not timely closed and remains slightly ajar for a while, signals of visceral information erroneously enter the consciousness block. In most cases such signals will be perceived merely as a noise and rejected. But sometimes visceral signals can resemble archetypes occupying the consciousness during a wakefulness and excite the corresponding neurons leading to the fantastic images of a dream.

Interestingly such a mechanism provides a ready physiological basis for psychoanalytic approaches based on interpretation of dreams [16]. Indeed, on the one hand the subject of dreams will most probably be determined by neurons having the lowest thresholds and such neurons correspond to the most active archetypes in the consciousness during wakefulness. On the other hand it seems visceral afferent impulses constitute one of the most important ingredients determining unconscious psychical functions [20].

Less harmless situation can arise if the gating of the consciousness block does not properly switch even after long periods of time. In this case persistent nocturnal nightmares might constantly interrupt normal sleep.
Figure 1: Schematic view of information flow in the brain during wakefulness (up) and during sleep (down). Solid and dashed lines show active and blocked signal transmission channels, respectively.
If upon a transition from wakefulness to sleep the consciousness block switches normally but the switching of the motor activity block is delayed, some visceral inputs can activate spinal cord motoneurons and lead to sudden limb movements. Such a sensorimotor disorder is called restless legs syndrome and it affects from 1 to 10 percent of the population \[^{21}\]. Interestingly, it was found that restless legs syndrome prevails in patients with intestinal disorders \[^{22}\]. Visceral theory of sleep provides a simple mechanism, just described, underlying these, otherwise mysterious, comorbidities.

Another harmless sleep pathology is hypnagogic hallucinations which appear before falling asleep under the obligatory condition of low level of illumination. Gates to the consciousness and motor activity blocks are still not closed, as well as the conduction of visual information to the cortex, but the pressure of sleep already opens the pathways for visceral afferentation to the cortex. Because of low level of illumination, the intensity of the visual stream is comparable with that of the opened visceral stream and visceral signals can induce visual phantoms superimposed on the real visual scene which is still being perceived \[^{16}\]. As a result a hallucination of large moving beetles, sensation of the wavelike movements of the floor or deformation of particular objects can appear. Hypnagogic hallucinations are eliminated if one turns the light on because the arousing effect of bright light forces switching off of the visceral inputs.

It may happen that upon arousal the consciousness block switches normally but the motor activity block is still blocked. In this case the so called sleep paralysis syndrome can arise: people for some period of time are unable to perform any kind of voluntary movement while having an appropriate perception of the environment. After some time (from several seconds to several minutes) the gate to the motor activity block is opened and the sleep paralysis passes away.

Visceral theory of sleep can simply explain even the mysterious phenomenon of somnambulism (sleepwalking) \[^{16}\], which in the past was thought to be due to demons or other supernatural phenomena \[^{23, 24}\]. Sleepwalking is more common in childhood, where it is typically benign and as a rule disappears by late adolescence, than in adults, where it has substantial harm potential. It occurs when the brain does not fully awaken from a deep sleep. in particular, according to the visceral theory of sleep, the gate to the consciousness block for some reason remains blocked after arousal. Sleepwalking can last from less than a minute up to an hour or more. Sometimes sleepwalkers can perform very complex things during this time interval, like prepare a
meal, play a musical instrument, drive a car, vocalize or even have conversations or sex with strangers, yet they do not have conscious awareness and their responsiveness to the environment, as well as their mental abilities such as memory, planning, and interacting with others may be greatly reduced or entirely lacking [24].

If during a sleep the gates to the consciousness and motor activity blocks become simultaneously opened, a condition more severe than the restless legs syndrome, the so-called REM behavior disorder first described in 1986 [25], can occur. In REM behavior disorder unusually vivid dreams and nightmares are accompanied by vigorous behavior and violent confrontations with the phantoms of dreams. For example, a 73-year-old very pleasant, mild, and considerate retired librarian during his vivid and violent dreams used to jump out from the bed, breaking objects in the room and damaging furniture, and more horribly, hitting, slapping, and even choking his wife a couple of times a week during his sleep [24].

3. The Visceral Theory of mental disorders

In the previous section we described some transient sleep disorders caused by inappropriate gating of external and visceral information streams in the brain. But what happens if for some reason some gate elements are not properly functioning permanently?

The striking similarity between psychotic phenomena during REM behavior disorder and symptomatics of schizophrenia lead to a hypothesis [26, 27] that schizophrenia could be a REM disorder, a kind of permanent dream attack while awake, a “waking reality processed through the dreaming brain” [26].

The visceral theory of sleep prompts to suggest a stronger hypothesis: all mental disorders are caused by failures of gating elements of the brain information processing system because of which visceral information is permanently present in brain’s “universal processor” and during wakefulness is interpreted by the brain as coming from external sources. So to say, psychiatric illness is a condition when a dreaming reality caused by unblocked visceral signals is processed as real by the waking brain.

Wrong switching of the visceral information stream is harmful not only because it can lead to a distortion of perceived reality and as a result to the brain’s irrational response. It seems plausible to imagine that a situation when a gate (or some gates) on the way of visceral information stream
remains open during wakefulness is stressful for the brain’s information processing system because the majority of the visceral signals will be interpreted as a noise. A continuous struggle with this “noise” can exhaust brain’s adaptive mechanisms and in a long run lead to dysregulation and breakdown of mental functions and abilities not directly connected with the faulted gates.

The well known fact that sleep and circadian rhythm disorders accompany almost every psychiatric illness \cite{28, 29, 30} can be considered as an indirect confirmation of the visceral theory of mental disorders if we embrace the visceral theory of sleep hypothesis.

The dominant model for sleep-wake cycle regulation today is the two-process model of Borbély and Wirz-Justice \cite{31, 32}. According to this model two processes, a homeostatic process and a clock-like process controlled by the circadian pacemaker, govern the sleep-wake cycle. Interestingly, multiple lines of evidence suggest that bipolar disorder can be considered to a large extent as a disorder of circadian rhythms and sleep-wake processes \cite{33, 34}.

Circadian system utilizes a special non-visual photoreceptors, different from the usual rods and cones of the mammalian retina, to differentiate darkness from light and synchronize the biological clock with the natural day-light cycle. Although their existence was suspected by Clyde Keeler already in 1927, such photoreceptors were discovered only recently \cite{35, 36}.

Circadian photoreceptors use a photopigment, most probably melanopsin, with a peak sensitivity at approximately 480 nm (blue light). If dysregulation of the circadian rhythms indeed plays the central role in symptomatics of bipolar disorder, it is expected that manipulating a blue light exposure of bipolar patients may have therapeutic potential. Interestingly, preliminary studies indeed report mood stabilization and reduced manic behavior in bipolar patients who wear at night special glasses with amber lenses that block blue light \cite{37, 38}.

A particularly striking example of the effectiveness of light therapy (or rather more precisely, dark therapy) is described in \cite{39}. A bipolar patient cycled rapidly between depression and mania. No medications were used for his treatment. Instead he was asked to remain at bed in complete darkness for 14 hours each night. The response to this dark therapy was dramatic: notwithstanding severe and unremitting rapid cycling for several years prior to the treatment, his mood stabilized within several weeks and he experienced a complete cessation of cycling.

As is well known, Lithium is the classic mood stabilizer commonly used in the treatment of the bipolar disorder. It seems this therapeutic effect of
Lithium is due to its ability to alter circadian rhythms. As various studies indicate [40], Lithium acts directly on the molecular clocks, although its chronobiological effects are not completely understood.

Within visceral theory of mental disorders, the association between circadian rhythm disruptions and bipolar disorder is understood through the role circadian rhythm plays in the control of gating elements of brain’s information processing system.

We can expect that the continues presence of visceral noise during wakefulness can affect visual and other perceptions. The extreme manifestations of this are hallucinations inherent of schizophrenia. However more delicate effects are also not excluded if the level of noise is not very high. In this respect binocular rivalry presents an interesting test ground for such putative influence.

When different images are presented to each eye simultaneously, instead of a superposition of the two images, perception alternates spontaneously between competing monocular views every few seconds. This phenomenon is called binocular rivalry and some research indicate that noise might be a crucial force in rivalry, frequently dominating the deterministic forces [41, 42].

In light of our hypotheses that the visceral noise plays a fundamental role in mental disorders, we expect that the perceptual rivalry will be affected in patients with psychiatric illnesses. Some evidence shows that this is indeed the case. It was found [43, 44] that in bipolar patients alternation rates were slower than in normal controls even during remission, while the rates during depressive episodes were significantly slower than during remission.

In some studies schizophrenia and major depression patients don’t show the altered rivalry rates compared to the control group [45]. The transition between the two alternate percepts in binocular rivalry is not always clean, however, and a mixing of the two images may be seen. It was found [46] that patients with schizophrenia showed a trend toward less mixed perceptions than controls. Besides, other studies found consistently slower binocular rivalry rates in participants with schizophrenia with the conclusion that abnormally-slow visual processing may be a feature of psychosis in general rather than a feature specific to bipolar disorder [47].

Motion-induced blindness is another interesting oscillatory phenomenon in visual perception in which small but salient visual targets disappear intermittently from the visual awareness when surrounded by a global moving pattern. Sometimes it is considered just as a form of perceptual rivalry because its temporal oscillation pattern of disappearance and reappearance is
highly correlated with the pattern reported for binocular rivalry in the same individual [48]. Interestingly but consistently with what was found in binocular rivalry, significantly lower rates of the motion-induced blindness were found in schizophrenia-spectrum disorder participants than in the control group [49].

Somewhat paradoxically, schizophrenia patients show diminished susceptibility to optical illusions. For example, to healthy participants a hollow mask will look convex, perceived as a normal face even when they are really seeing the concave side, whereas patients with schizophrenia do not perceive the hollow-mask illusion [50, 51]. Recent brain-imaging and electrophysiology studies are compatible with the idea that individuals with schizophrenia and controls use different perceptual strategies to minimize errors in visual awareness [52]. Within the framework of visceral theory of psychiatric disorders, this change of perceptual strategy may be attributed to the presence of significant visceral noise in visual channel. An interesting fact that, similarly with the patient group, sleep-deprived medical staff show a remarkable impairment of binocular depth inversion [50] indirectly supports this supposition in light of the visceral theory of sleep.

The Necker cube is a classic example of bistable perception. As perceptual reversals of ambiguous figures have several features in common with the binocular rivalry [53], it is not surprising that the rate of perceptual alternation of the Necker cube was reported to be slower in patients with bipolar disorder (but not in patients with schizophrenia) [54]. Interestingly, neural network simulation of Necker cube perception suggests a view that manic states arise from excessive levels of cortical noise that destabilize neural representations [55]. In case of mild mania, this noise might be even beneficial because it increases the speed in which the perceptual system abandons one particular scheme of organization of perceptual information in favor of reassembling these same elements into a new meaningful scheme. As a result creative thinking is facilitated due to this ability to parse elements of experience in a different and unexpected way [55]. There exists an ample evidence of the link between creativity and bipolar disorder [56, 57, 58, 59]. According to Jamison [58], biographical data suggests that bipolar disorder may have affected, among others, Hemingway, Faulkner, Fitzgerald, Dickens, O’Neill, Woolf, Handel, Ives, Rachmaninoff, Tchaikovsky, Keats, Gauguin, O’Keefe, Munch, Pollock. However still many questions do remain regarding this mysterious connection [59].

Illness in general, and mental illness in particular, is a condition of a per-
son being far from equilibrium and in this respect an individual in a period of illness resembles a chaotic system \[60\]. In a chaotic system multiple options become available and small external perturbations can lead the system to bifurcate in a totally new direction and obliterate preestablished daily routines in favor of increased creativity \[60\]. Even a normal creative process in its highest intensity can so closely resemble mental disorder that Ellenberger calls such a state “creative illness” \[61\]. “To paraphrase the poet, a genius does not always return from hell with empty hands; he or she sometimes emerges bursting with vitality and insight” \[62\].

If the mental illness is really caused by the presence of visceral noise, theoretically there exists a possibility of “software” self-healing of the troubled brain if it manages to recognize and properly handle malicious visceral signals. Interestingly, we can point to at least one such miraculous emergence from schizophrenia of John Forbes Nash, a mathematical genius who was made famous by Sylvia Nasar’s biography A Beautiful Mind \[63\].

At a peak of his mathematical career Nash became ill with schizophrenia and lead for decades a miserable life under the generous support of his former wife Alicia. Then he miraculously recovered from the illness and this recovery became possible because he managed to recognize paranoid ideas and voluntarily reject them although he was still plagued by paranoid thoughts and voices \[63\]. Interestingly, on the onset of his illness when he was asked how could he, a mathematician devoted to reason and logical proof, believe that aliens from outer space recruited him to save the world, he answered: “because the ideas I had about supernatural beings came to me the same way that my mathematical ideas did. So I took them seriously” \[63\].

Nash believed that aliens were trying to contact him through the New York Times newspaper. When a natural human tendency to seek patterns in random information is exaggerated at such a level that a person begins to see patterns and connections in random or meaningless data, such a condition is called apophenia by a German neurologist and psychiatrist Klaus Conrad, who considered it as a second stage in development of schizophrenia \[64\]. At the first stage, which Conrad called “Trema” (stage fright), patients have a delusional mood that something very important is about to happen. Perceiving an abnormal meaningfulness where none is actually present and attributing mental states to it might be a result of visceral noise and different stages of this phenomenon might reflect a fight of the brain with this noise. The visceral noise may induce an exaggeration of the normal human tendency to attribute mental states and lead to a hyper-associative cogni-
tive style characteristic of creativity. That apophenia may be underpinned by a hyper-associative cognitive style, rather than by a dysfunction in the assessment of causality, was suggested in [65].

The research on connections between apophenia and bipolar disorder is thin but personal accounts from manic patients suggest such a connection [66]. For example Virginia Woolf, a famous English writer who suffered from bipolar disorder, once listened to the chirping of the birds and was convinced they were speaking Greek [67].

Another interesting example of brain’s ability to curb phantoms coming from unconscious (visceral noise) is provided by creative illness of Carl Gustav Jung. After the acrimonious split from Sigmund Freud in his late thirties, Jung experienced a massive “mid-life crisis”. Some his visions and dreams, that he was unable to interpret, convince Jung to undertake a thorough investigation of his own unconscious and in 1913 he embarked on his most dangerous experiment.

The Red Book [68], which was never published in Jung’s lifetime, provides a dramatic and a very personal account of this experiment which lasted almost twenty years. It describes Jung’s reckless and insidious descent into the hell of his own unconscious what many believe to have been a madness. Jung recalled in 1925: “it seemed to me I was living in an insane asylum of my own making. I went about with all these fantastic figures: centaurs, nymphs, satyrs, gods and goddesses, as though they were patients and I was analyzing them” [68]. When Jung’s longtime friend and translator R. F. C. Hull read after Jung’s death The Red Book, written and illustrated in the manner of a medieval manuscript, he remarked “Jung was a walking asylum in himself, as well as its head physician” [69].

Rather than being defeated by psychosis (and he feared this during his active imagination experiment), Jung courageously confronted it, explored what he found there, and returned to the outer world renewed and more creative. As Jung himself remarked in this regard, “the reason why the involvement looks very much like a psychosis is that the patient is integrating the same fantasy-material to which the insane person falls victim because he cannot integrate it but is swallowed up by it” [68]. Alas, most of the mental patients proved unable to integrate fantasy-material emerging from visceral noise.
4. Concluding remarks

The main idea of visceral theory of sleep is that the processing of external and internal information streams by brain are largely separated. The same cortical neurons that process exteroceptive information in wakefulness switch during sleep to the processing of the interoceptive information. Thus during sleep the brain plays a dual role: from one side it is involved in the scanning of all life supporting systems, and processing of the relevant visceral information, and from the other side the brain itself is a paramount visceral organ also requiring control and management of its state.

However such a scheme of organization of the main information flows in the brain logically implies a possibility of errors and desynchronization in switching of the external and internal information streams by various gating elements of the brain information processing architecture. Anticipated synchronization errors allow us to explain various transient pathological states connected with sleep, as indicated above. But if gate elements are not properly functioning constantly more serious consequences may appear.

We hypothesize in this article that the primary cause of mental illnesses is just such a permanent fault in switching of the external and internal information streams during sleep-wake cycle as a result of which visceral signals are permanently present in the cerebral cortex biasing the normal information processing.

At the present time a serious drawback of this hypothesis is that we have no understanding of the role emotions play in this picture. The counter-intuitive James-Lange theory of emotions asserts that an emotion is the feeling of bodily changes, so closely related to the visceral information. This theory had a profound impact on philosophy and psychology, but at the same time it has been widely criticized, partly maybe due to misinterpretation of the James’ views on these matters \cite{70}. Anyway, at present we do not have a clear understanding what emotions are and what roles do they play in brain information processing.

An attempt to combine the visceral theory of sleep with the Simonov’s need-informational theory of emotions was undertaken in \cite{71}, but we feel that emotions play more serious role in the brain information processing architecture than anticipated in this work. This is especially true as far as the mental illnesses are concerned.

Besides there is a growing evidence that gut microbes are significant part of the unconscious system regulating behavior \cite{72}. Genes within the human
gut microbiota significantly outnumber human genes in the body and they are capable of producing a wealth of neuroactive compounds that influence brain development and functioning [72]. At present we have no idea how gut microbiota interacts with the external and internal information flows in the brain.

Notwithstanding this drawbacks, we hope that the hypothesized visceral theory of mental disorders will stimulate a fresh look on the connections between the organization principles of the brain information processing and mental illnesses.

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