THE THREE CAMPS OF WHERE THE CONSCIOUSNESS ARISE

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Dear editor,

The scientific study of consciousness began to develop mainly with the father of psychology, William James, in the 1880s and was once influenced by behaviorism into its winter. Having published *The Astonishing Hypothesis*, Crick (1994) broke the "shunning of consciousness" in neuroscience and psychology at the time, and together with contemporary pioneers such as Baars (1988) and Edelman (1992), led to a new golden age of investigation of consciousness since the 1990s (Seth 2018). Then, the "neural correlate of consciousness" (NCC, cf. Koch et al. 2016) has been a well-known scientific topic with enduring debates. Various theories of consciousness have begun to emerge in the field, including neuroscientific theories propounded by Koch (2004), Tononi (2004), Rosenthal (2005), Lamme (2010), Graziano (2010), and Dehaene (2014), etc., also views of quantum mainly supported by Hameroff and Penrose (1996, 2014). There are disputations between their claims in several aspects, such as both the connotation and the mechanisms of consciousness, which has led to projects aimed at testing and evaluating various theoretical claims (Melloni et al. 2021, Reardon 2019).

Despite nearly a century and a half of exploration, the problem of consciousness has yet to be genuinely saved. Gazzaniga, "the father of cognitive neuroscience," suggests his unique viewpoint in the book *The Consciousness Instinct*. One might wonder whether this suggestion is merely one of the competing theories or if it can helpfully reconcile the heated debates. The book is divided into three parts. Part I (Chapters 1-3) combs through the exploration of consciousness and the brain in human history, from the early philosophical pioneers to the formation of the science of consciousness. This brief history allows us to see how the connection between consciousness and the brain has been gradually uncovered. In the following two most essential parts, Gazzaniga spends the most ink beginning to present us with his view of consciousness, including an architecture by which consciousness works on a biological system like the brain and the reasonable account for the "explanatory gap" of consciousness (Levine 1983).

Gazzaniga was invited to provide neuropsychological guidance to neurology residents. This experience and his split-brain research provided rich cases for *The Conscious Instinct*. Through these patients (which is applied throughout the book, mostly in chapter 6), we can see how their consciousness changes after certain damages or abnormalities of the brain. Still, consciousness itself is fundamentally hard to eliminate. In chapters 4 and 5, Gazzaniga elaborates on a layered and hierarchical architecture in the brain. Our indivisible consciousness is actually generated by numerous relatively independent processing units (i.e., modules). "There are a tremendous number of brain lesion cases that paint a similar picture: Damage or dysfunction in brain region X causes a change in behavior Y, but consciousness almost always remains intact. The modular brain makes consciousness resilient because of the plethora of possible paths that can lead to a conscious moment." (Gazzaniga 2018, p. 150) Individually packaged modules not only preserve the integrity of consciousness in accidents of several modules but also increase the complexity of the system as a whole by introducing new modules throughout evolution. In Chapter 6, in conjunction with various cases, he sees the subcortical emotional structure as the engine of the whole hierarchical system of consciousness.

Chapters 7 and 8 devote to the "hard problem" (Chalmers 1995) of consciousness. Gazzaniga appeals to the remarkable works of Pattee (2007, 2013, 2021) on symbol-matter complementarity. In this view, "duality" is a necessary and inherent property of any agent that can live to evolve. Matter, as we know, follows the physical laws of determinism, while symbols operate to abide by the rules of arbitrariness. Therefore, facing the issues of life, including the mind, a single model is not always enough. We shall understand organisms with complementary models. This new approach of epistemology also provides a solid metaphysical foundation for Gazzaniga's hierarchical architecture of the mind.

In Chapter 9, Gazzaniga conceives a metaphor of boiling bubbles to elucidate the proposed distributive architecture. The product of each module surfaces, bursting like "bubbles in a boiling pot," each time a fleeting part of our consciousness. The rising bubble shows us the scene of the tumbling water, and the complex of modules of consciousness emerges, which are both similar to the "continuous" story of a comic strip turning the pages. Consciousness emerging, as Damasio (2021, p. 40) puts it, "is a systems-level phenomenon. It calls for a rearrangement of the furniture of mind…." Finally, in Chapter 10, Gazzaniga discusses the very mechanism by which such a hierarchical architecture works in the brain. Based on his understanding of the complementarity of instincts, he argues that consciousness as a higher-order instinct wouldn't arise only in fixed brain regions. We need to focus on the neural design of the brain, which allows the brain to emerge into consciousness from a variety of sources and ways.

Ginsburg and Jablonka (2019, pp. 142-147) concluded that Damasio's work is the only one that relies specifically on emotion in the current neurobiology of consciousness. It must be said to have added at least one more striking member to the camp, the view of Gazzaniga. Comparing the subcortical emotional structure to an engine, Gazzaniga shows us that subcortical activity is the basis for further cortical activity. Further, it reflects the emotions and feelings that hold an early position in evolution as the central role of consciousness. On the contrary, the cortical structure may be just the "icing on the cake" that extends the conscious mental content widely.

Nevertheless, it is worth considering that Lau (2022) also argues the meaning of the metaphor of "engine" in his exploration of neural correlates of consciousness (NCCs). The engine of a car is not genuinely necessary for its movement. Because if the engine breaks down, we can still push the car forward, or it may have been equipped with an electric motor as an alternative. Not only that, but if the engine is running effectively with lacking something others (e.g., the lack of wheels), the car would not be able to move. In terms of consciousness, it may be roughly analogous.

The rivalries and collaboration at a crossroads between the various alternative theories have become most notable currently in the science of consciousness. All candidates have claimed their own models or mechanisms of consciousness. Specifically, the "front" camp predominated by the Global Workspace Theory (GWT, cf. Mashour et al. 2020, Sergent et al. 2004), the Higher Order Theory (HOT, cf. Brown et al. 2019, Lau et al. 2011), and the Predictive Processing (PP, cf. Seth et al. 2021, Solms 2018), believes that consciousness emerging relies on the anterior regions of the neocortex which are responsible for some specific cognitive processes underlying post-perceptual decision and report, etc. Yet the "back" camp constituted by the Integrated Information Theory (IIT, as its recent version cf. Marshall et al. 2023, Tononi et al. 2016) and the Recurrent Processing Theory (RPT, cf. Lamme 2010, 2018), etc., proposes it is adequate to give rise to consciousness in the posterior regions which are responsible for certain sensory activities.

Usually from an evolutionary biological perspective, the new approach of the "emotional" view of consciousness in the current study of consciousness extends the debates on the regions for consciousness to locate from the neocortex of conventional ideas to the subcortical structure, a three-stage candidate (the "front" camp, the "back" camp, and the "subcortical" camp, see Table 1).

In July 2023, the results of the initial adversarial cooperation between IIT and GWT revealed that both theories have imperfections in their predictions and that both require a sort of improvement (Lenharo 2023). It seems that, as Lamme (2018) argued before, with the intense controversy and stalemate remaining, each theory may require more "missing ingredients". Some ingredients in this evolutionary viewpoint of consciousness may be the key to reconciling the debates between those two camps.

Emotions play as a reward and punishment system that tells an organism how to act in its quest for survival. Organisms are motivated by positive emotions, while negative emotions can lead to suspicion or disaster. Both types of emotions are powerful drivers of behavior and help evaluate the circumstances, despite being relatively simple on a mental level. In contrast to non-conscious beings (only the most basic emotionality), Damasio A. and Damasio H. (2022, 2023) deem that the conscious is not only able to represent the external world as mental images but also relate the images to their internal homeostasis, thus having a sense of self, a perspective of subjectivity. Thus, emotional feelings are spontaneously conscious mental events and have been selected for the progressive ability of organisms to advance their living and being. While as for Panksepp and Biven (2012), Gazzaniga mentioned in his book, two types of consciousness should be differentiated: the evolutionarily old affective consciousness and the new cognitive consciousness.

The crucial issue here is that we need to track the necessary and sufficient mechanisms of consciousness corresponding to the so-called "minimal phenomenal experience" (Metzinger 2020). It is important to note that such a mechanism or condition describes a kind of *criticality* in terms of the global transformation from the unconscious to the conscious rather than discussing a shift in local experiential content. That is, with this

Table 1: The three camps where consciousness arises

The camps	Claims	Members
The "front" camp	Consciousness emerging relies on certain anterior regions of the neocortex.	GWT, HOT, PP, etc.
The "back" camp	It is adequate to give rise to consciousness in the posterior regions of the neocortex.	IIT, RPT, etc.
The "subcortical" camp	The subcortical emotional system plays the role of engine for consciousness to arise.	Damasio's, Gazzaniga's, etc.

condition being met, there would be more or less experience. However, once the condition broke to lack though a little, there would not be any experience. For any experience, no matter how complex it is (from a state of pure consciousness to conscious reasoning), the present state of the brain meets at least this condition. Therefore, corresponding to the debates between these theories, it would benefit from picking out the appropriate treatment among: (1) whether these three candidates play their respective roles in giving rise to consciousness, which the "yes" means all three are parts of the fundamental mechanism, or (2) just one of them (e.g., the subcortical emotional system) is enough to constitute a minimal experience, which means the rest should be excluded, or (3) any of them give rise separately to different forms of consciousness, which means consciousness should be treated really as a hybrid concept with all of the camps for each formation. Even with Gazzaniga's arguments here, the answer still needs to be entirely sure. More empirical findings in the future may lead to a satisfactory conclusion.

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LARGE-SCALE BRAIN NETWORKS IN CHRONIC AND SMOLDERING SEROTONIN SYNDROME

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Dear editor,

Serotonergic antidepressants are used to treat a variety of conditions, including depression, anxiety disorders, panic disorder, obsessive-compulsive disorder (OCD), post-traumatic stress disorder (PTSD), premenstrual dysphoric mood disorder (PMDD), bulimia nervosa, and chronic pain disorder. One of the most dreaded side effects of serotonergic agents is serotonin syndrome. With the widespread use of various serotonergic agents, the incidence of serotonin syndrome is estimated to be increasing worldwide. However, symptoms of serotonin syndrome vary and may go unnoticed clinically (Debeljak et al. 2021). Early diagnosis is important because timely and effective treatment strategies can prevent undesirable morbidity and mortality (Zhan et al. 2021). The typical triad of signs is neuromuscular abnormalities (convulsions, myoclonus, tremors, hyperreflexia, and myotonia), autonomic hyperactivity (hyperthermia, tachycardia, hypertension, diarrhea), and altered mental status (excitement, confusion, anxiety, coma). Several diagnostic criteria have been proposed for serotonin syndrome, but the most accurate is the Hunter serotonin toxicity criteria (Dunkley et al. 2003). The symptoms suggest that serotonin syndrome is the acute drug toxidrome, which is a group of clinical signs and symptoms associated with a toxic ingestion or exposure (Spadaro et al. 2022). However, the acute typical serotonin syndrome is only the tip of the iceberg of this syndrome. Under the surface of the acute toxidrome, a state of serotonin excess smolders chronically without clinical recognition. This condition is called chronic or smoldering serotonin syndrome. Chronic serotonin syndrome is a condition in which symptoms resulting from excessive intrasynaptic concentrations of serotonin persist for more than 6 weeks and meet Hunter's criteria (Prakash et al. 2021). According to a detailed report of 14 cases of chronic serotonin syndrome, nonspecific symptoms, i.e., chronic pain, stiffness, insomnia, restlessness, and fatigue, were more important than neuromuscular symptoms for the proper diagnosis (Prakash et al. 2021).

Serotonin is an important neurotransmitter in the central nervous system. The activity of neurotransmitter-related neurons synchronizes low-frequency oscillations within different brain regions, affecting the baseline level of activity and its balance (Conio et al. 2020). Therefore, understanding serotonin syndrome as a change in neuronal firing patterns caused by excessive serotonergic neurotransmission might help in early diagnosis. Serotonergic neurons reside in the raphe nucleus and project to many areas of the brain, including the prefrontal cortex, amygdala, and hippocampus. Brain functions are formed by functional connections between different neural regions, which are referred to as large-scale brain networks, such as the executive control network, the salience network, and the default mode network (De Ridder et al. 2022). These large-scale brain networks strengthen or weaken functional connectivity with the brainstem and spinal cord through subtle increases or decreases in neurotransmitters. Serotonin neurons may regulate multiple aspects of cognition and behavior via modulation of large-scale brain networks. The studies using functional connectivity magnetic resonance imaging (fcMRI) have shown that serotonin excess increases the default mode network and decreases the salience network (Salvan et al. 2023). The default mode network plays a central role in intrinsic thought processes, but excessive activation of this network increases the brain's energy expenditure, making the brain tired, prone to distractions, and dominated by negative emotions. To begin with, in patients with depression and chronic pain, for whom serotonergic agents are indicated, pain-related somatosensory cortex activity is functionally strongly linked to a self-expressive default mode network (De Ridder et al. 2022). Administration of serotonergic agents to this condition may further reinforce the default mode network. When the default mode network is overactive, the autonomic nervous system in the brainstem connected to it becomes abnormally active, causing a variety of dysautonomic symptoms, including pyrexia, tachycardia, blood pressure changes, palpitations, and sweating. Activation of the default mode network by serotonin excess risks forming an acute serotonin toxidrome ready state. In our unpublished data, we interviewed 18 patients treated for typical serotonin syndrome and found that 15 (83.3%) experienced distraction, significant fatigue, unexplained back pain, palpitation and irritability for several weeks to 6 months before onset. Unexplained physical or autonomic symptoms prior to the diagnosis of a typical serotonin syndrome may be a chronic or smoldering serotonin syndrome, although clinically unnoticed. The incidence of serotonin syndrome is largely unknown, because especially mild cases are frequently overlooked (Debeljak et al. 2021). Recognizing chronic or smoldering serotonin syndrome can help prevent acute serotonin syndrome.

Chronic serotonin syndrome is a developing concept. It presents with nonspecific symptoms of generalized pain, stiffness/rigidity, insomnia, restlessness, and fatigue. A high level of clinical suspicion is needed to identify this syndrome. Viewing serotonin syndrome not only as a drug toxidrome of acute serotonin excess, but also as an alteration of large-scale brain networks caused by serotonin excess, may help conceptualize chronic and smoldering forms of serotonin syndrome and enable early intervention. A limitation of this paper is that we have not directly measured large-scale brain network changes in serotonin syndrome, which requires further study.

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