

REVIEW ARTICLE

The central role of emotion-driven self-organization
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Abstract

This paper brings together, from an enactivist and self-organizational perspective, two separate but parallel streams of research on the role of emotion in conscious and cognitive processes. There is already an extensive and growing body of research on the subcortical and limbic influences on the neuroplasticity of many brain functions, including cortical ones. At the same time, among cognitive theorists and philosophers of mind, there has been renewed interest in the enactivist and dynamical systems structure of mental processes, with growing attention to emotion as a driver of action affordances and action imagery that shape consciousness. However, there has been little attention to the way these two streams can enhance each other's explanatory coherence. Neuroplasticity emerges as a common thread linking both streams. The theory of self-organization, as applied to emotion-driven enactivity in conscious functions, can serve as a conceptual bridge between these two emerging areas of research. Here, we offer a theoretical framing of the endogenously action-initiating dynamics of consciousness and its neural substrates as driven and shaped by emotion, with implications for both clinical intervention strategies and empirical research.

Keywords: Neuroplasticity; Emotion; Enactivism; Self-organization; Neurophenomenology; Embodied mind

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1. Introduction

The purpose of this review is to incorporate existing data into a coherent theoretical understanding of the way emotion affects various forms of consciousness, particularly those not traditionally considered to be emotion-related. The brain's impressive neuroplasticity is a function of its status as a living, rather than inanimate, system. This, in turn, allows cognitive functions to be systematically organized in the service of the organism's motivational purposes, many of which are expressed through emotions. McEwen and Sopolsky,¹ drawing on animal studies, demonstrate how emotional stress can significantly impair hippocampal functioning. Shors *et al.*² and McEwen *et al.*³ further show that the hippocampus regulates neuroplasticity in synaptic reorganization across multiple levels of brain function, including cortical processes involved in cognitive skills not typically associated with emotion.

These and other studies have shown that both emotional stress and clinical depression impact neuroplasticity, even at the level of cellular morphology. A corollary

of this is that, consistent with the work of Panksepp,⁴⁻⁶ Watt,⁷ and others, conscious experience begins with motivational brain activation and only subsequently involves perceptual brain areas. Aurell⁸⁻¹⁰ and others have tracked this timing, showing that emotional brain areas activate first, followed by cortical activity several 100 ms later. The all-too-tempting stimulus-response paradigm is therefore not only misleading in the study of emotional consciousness but also inadequate for understanding consciousness itself and its various forms of expression.

An increasing number of neuroscientists and cognitive theorists now suggest that only organisms capable of emotion and motivation can possess any form of consciousness, whether emotional, perceptual, or intellectual. The above-mentioned studies, along with others cited later, indicate that emotion plays a critical role in shaping neuroplasticity, which in turn distinguishes living, conscious organisms from computational machines such as computers and robots. It is not merely the specific, replaceable micro-constituents of the system that matter, but more importantly, the self-organizing pattern of activity needed for conscious processes. Such systems can reorganize their components to compensate for disruptions in ongoing activity, exchanging energy and materials with their environment to maintain a stable organizational pattern. Jaak Panksepp's extensive body of work identifies a small number of endogenous, relatively independent motivational/emotional systems that activate in this manner. These systems not only energize the brain's self-organizing activities but also influence the efficacy of neuroplasticity at all levels of brain function.

Panksepp⁴ explicitly differentiates this approach from the behaviorist tradition, which conceptualized conscious processes as causal outcomes of external stimuli rather than as endogenous, self-initiated actions of the organism. While the term "behaviorism" has fallen out of favor, many research paradigms still implicitly follow its theoretical assumptions. The stimulus-response model remains widespread, often assuming that mental, emotional, and conscious processes arise from perceptual inputs and visceral reactions. How many conference presentations on the neuropsychology of emotion begin with: "First, we perceive a stimulus, for example, we see a bear in the woods, and then..." After four centuries of explaining mental processes through linear cause-and-effect mechanisms, it remains all too natural to assume that a conscious event must be the causal result of some preceding external stimulus and that such physical processes are ultimately reducible to linear causal sequences at a more "micro" level.

However, by the late 20th century, a Kuhnian pre-revolutionary moment emerged around the problem of

consciousness, disrupting this convenient reductionist scheme. It became increasingly evident that the distinction between conscious and non-conscious "information processing" systems could not be explained through linear mechanisms alone. Chalmers,¹¹ in 1995, articulated to analytic philosophers of mind and computationally oriented cognitive theorists that while we may correlate certain brain processes with specific conscious experiences, these constitute the "easy problems" of consciousness. The "hard problem"—why certain physical processes are accompanied by consciousness while others are not—cannot be answered simply by identifying physical correlates of the conscious processes. Establishing such correlations merely restates Chalmers's question; it does not resolve it. The central issue remains: what fundamentally differentiates consciousness and non-conscious computations, such as those occurring in AI systems?

As a result, numerous scholars now propose the idea that consciousness itself requires the capacity for emotion and motivation, across all its manifestations, whether emotional, perceptual, or intellectual consciousness (e.g., Damasio,¹² Ellis,^{13,14} and others as discussed below). Emotion appears to be the key difference between living, conscious organisms and computational machines. To explain this foundational distinction, theorists increasingly turn to self-organization theory in complex dynamical systems (e.g., Kelso,¹⁵ Ellis and Newton,¹⁶ Ellis^{17,18}). Self-organizing systems can appropriate, rearrange, and replace their own micro-constituents to maintain continuous patterns of activity.¹⁹ It is this widely distributed pattern, not the replaceable micro-constituents, that is necessary for conscious processes. Such systems, just as Merleau-Ponty's^{20,21} notion of "psychophysical wholes," possess the ability to reorganize themselves in response to disruptions of the ongoing pattern.

2. Method

The review aims to connect empirical work on neural plasticity with related formulations of the enactivist self-organization approach to consciousness, especially emotional consciousness. In recent years, there has been a surge in empirical research on neuroplasticity and its relationship to emotional brain processes, allowing only a selective sampling to be included here. Much more can be found by simply searching the terms "neuroplasticity" in connection with "emotion." Since the hypothesis proposed here is that emotion-driven self-organization underlies higher cortical functions, most of the studies considered involve brain circuitry that may help elucidate those connections. The empirical studies selected span much of the 21st century: 24 from the past two decades, and another 18 from the 1990s, often laying the groundwork

for subsequent research. The 28 theoretical works cited for comparison date back to the 1980s and 1990s, when interest in a self-organizational approach to consciousness and emotion began to flourish. The empirical findings serve both as support for the enactivist theoretical framework and as a basis for better understanding the role of emotional brain processes in forms of consciousness not traditionally associated with emotion. Neuroplasticity is the primary point of connection between theory and empirical data. The brain research shows that emotional processes, acting through neurotransmitters and ascending synaptic circuitry, influence the effectiveness of neuroplasticity in related cortical functions. Together, these empirical data tend to support the enactivist self-organization approach to consciousness and cognition. In the final section, we discuss possible therapeutic applications and directions for future research.

3. Separate but parallel streams of research in neurophysiology and cognitive theory

3.1. The neurosciences

Recent research on neuroplasticity has deepened appreciation for the enactive structure of emotion-driven variations at both the cellular and synaptic levels of brain reorganization.

Shors,²² building on earlier work,² shows how emotional processes, especially depression, affect adrenergic systems that regulate cortical activity through the release of epinephrine at the subcortical level. In other words, emotion at least partially governs the neuroplasticity of cortical substrates associated with conscious and cognitive function. This finding aligns with Panksepp's explanation²³ of the impact of what he terms the SEEKING system (one of several proposed endogenous emotion systems, which he designates using ALL CAPS). The SEEKING system endogenously drives behavior and conscious processes by energizing multiple neurotransmitter systems that are globally active across the brain.

Consistent with the Shors' results, Ahmed *et al.*²⁴ focus on a specific emotional process—stress—and demonstrate that stress alters the brain's capacity for neuroplastic reorganization in areas associated with cognitive functioning. Similarly, Banasr *et al.*²⁵ find that stress reduces the generation of prefrontal brain cells in rats, while Cook and Wellman²⁶ report stress-induced changes in dendritic structure within the prefrontal cortex of rats.

Regarding constraints on neuroplasticity, Bavelier *et al.*²⁷ identify emotional processes that reduce certain “brakes” on plasticity. Some of these brakes are structural, such as perineuronal nets or myelin, that inhibit neurite

outgrowth, while others are functional, directly affecting the excitatory-inhibitory balance in local circuits. Their study finds that adult plasticity can be enhanced by lifting these brakes during development, including through the stimulation of endogenous neuromodulators.

Conversely, Holzel *et al.*²⁸ implemented an emotional stress-reduction intervention, which participants reported as subjectively effective. The researchers found a corresponding reduction in the density of right basolateral amygdala gray matter, suggesting that emotional regulation can induce structural reorganization in the brain. In line with this, Lakshminarasimhan and Chattarji²⁹ find that stress modulates the release of brain-derived neurotrophic factor, affecting structural plasticity in both the hippocampus and amygdala, regions implicated not only in emotional regulation but also in the cognitive symptoms of psychiatric disorders such as depression and anxiety.

Karatsoreos *et al.*³⁰ found that rats exposed to stress-inducing circadian disruptions exhibited decreased cognitive flexibility due to associated changes in neural architecture. This supports the idea that subcortical and limbic emotional factors can modulate neuroplasticity at the cortical level, helping to explain how the brain reorganizes and adapts to stress. Similarly, Liston *et al.*³¹ used a circadian rhythm paradigm to demonstrate that glucocorticoid oscillations affect the formation of new dendritic spines and the encoding of new memories, reinforcing the role of emotion in driving self-organizational neural changes linked to consciousness and cognition.

Other researchers have explored the implications of these mechanisms in clinical contexts. Brydges *et al.*³² show that juvenile stress leads to corticosteroid receptor imbalances, contributing to increased anxiety and decreased neuroplasticity in the limbic system during adulthood. Bessa *et al.*³³ and Wolpaw³⁴ argue that the effectiveness of antidepressant medications is due more to their ability to induce neuroplasticity than to their role in cellular regeneration. Conversely, Hill *et al.*³⁵ show that prefrontal activity can modulate limbic function: the reorganization of synaptic structures in the prefrontal cortex alters corticolimbic pathways, thereby inhibiting corticosterone secretion, an example of the brain's self-regulatory capacity to adjust neurotransmitter balance and synaptic connections in conditions like anxiety and depression.

With regard to the effect of emotion on “higher” brain functions, Jang and Kwon³⁶ emphasize that subcortical processes not only activate cortical areas through the reticular activating system (RAS), but also orchestrate consciousness through a specific stream that begins in the brainstem and ascends through the RAS. They write that

“Consciousness is mainly controlled by the ascending RAS, consisting of the brainstem reticular formation (RF), non-specific thalamic nuclei, basal forebrain, hypothalamus, and cerebral cortex.”^{36,p.200}

3.2. Enactivist cognitive theory

All of the above studies suggest that neuroplasticity, including at the cortical and even prefrontal levels, is heavily influenced by subcortical and limbic emotional processes. The study by Jang and Kwon³⁶ even suggests that consciousness *per se* depends on a specific pathway from the subcortex to the frontal areas. Given that neuroplasticity is inherently a self-organizational phenomenon, and as the enactivist approach to consciousness and cognition is grounded in the principle of self-organization, we might expect parallels between enactivism and neurophysiological work on neuroplasticity.

The enactivist approach to cognition can be traced back at least to Gibson,³⁷ who, in 1979, argued that we understand the world in terms of its action affordances. Even a newborn infant seeks out objects that afford sucking and understands them as such. Gibson, in turn, was indebted to the earlier work of Merleau-Ponty,^{20,21} who characterized the conscious organism as understanding its world through self-initiated action. At that time, however, little attention was given to how neurophysiology might fit into this picture. Neuroscientists then tended to conceive of the brain as a system of bottom-up causal sequences, which did not align easily with the holistic view proposed by Gibson and Merleau-Ponty. Only later did neuroscientists begin to recognize how neuroplasticity supports this self-organizational view.

As the enactivist approach evolved in the 21st century, Hurley and Noë,³⁸ among others, began to propose links between neuroplasticity and the self-organizing structure of consciousness as envisioned by enactivists. This development ultimately led to emotion-based “teleological” dynamics as proposed by Di Paolo,³⁹ Colombetti,⁴⁰ and Fuchs.⁴¹ Building on the inattentional blindness studies by Mack and Rock,⁴² Abrahamson *et al.*,⁴³ and De Jaegher *et al.*⁴⁴ showed how selective attention, affecting the content of perception, is itself controlled by action-initiating processes in the brain. We will explore this dynamic in more detail later.

Colombetti, as cited above, draws on neurophysiological evidence to show how the enactive structure of the mind is shaped by emotional processes, while enactivity in turn determines the content of perception and cognition. The dynamic resembles the functioning of Panksepp’s SEEKING system.

De Jaegher *et al.*⁴⁴ and others have extended the

enactivist approach to the realm of social interaction. Their ongoing work proposes that, as we perceive the subtle affordances that are possible or impossible in interpersonal contexts, our own actions relative to others constitute our perception of others as conscious subjectivities.

Fuchs, as mentioned earlier, combines neurophysiological data with the newly developing enactivist theory to argue that the organization of the brain is fundamentally holistic, rather than a bottom-up system in which micro-constituents determine the whole. His work significantly advances the integration of neuroplastic phenomena with the theory of self-organization at the core of the enactive approach.

Gallagher⁴⁵ explores how enactivism can inform psychotherapeutic practices. He incorporates the enactivist model of emotion and consciousness into practical methods that use emotion-driven causality of the motivational system to influence behavioral and cognitive outcomes. The organism, in this view, changes its own organizational structure as driven by emotion, where emotion itself exhibits a self-organizing structure, rather than the linear causal sequences of the older behaviorist model, which viewed perceptual inputs as the primary drivers interacting with internal micro-components. At a fundamental theoretical level, Di Paolo, as noted earlier, argues that autopoiesis, the ability for self-organization reflected in neuroplasticity, is grounded in what he terms “teleology” in a modernized sense. Action can be purpose-directed, and the organism’s purposes, within certain limits, can guide the appropriation and reorganization of micro-constituents needed to fulfill those purposes. It is important, however, to keep in mind the “within certain limits” qualification, and not attribute magical properties to the self-organizing system.

4. Toward a theoretical synthesis

As Di Paolo suggests, the capacity for self-organization introduces a kind of “teleological” dimension. Complex self-organizing systems maintain a degree of constancy in their ongoing organizational patterns by exchanging energy and materials with their environment. These systems strive not only to preserve stable patterns, reflected biologically in the principle of “homeostasis,” but also to explore: to seek stimulation, novelty of experience, environmental engagement, and intensity of feeling. This motivational tendency, whose suppression in clinical depression leads to diminished neural plasticity, was referred to in *Curious Emotions*¹³ as “homeo-exstasis.” Panksepp, whose pioneering research on the emotional brain spanned both human and animal subjects, identified this expansive motivational drive as part of an independent and

unconditioned SEEKING system.⁴ This system motivates curiosity, interest, exploration, and voluntary self-initiated action, as opposed to mere reactive behavior.

Panksepp characterizes the subjective or experiential dimension of the SEEKING system in the following way: “The extended lateral hypothalamic corridor [with ascending dopamine circuits and descending glutamatergic circuits] responds unconditionally [i.e., without any previous learning or conditioning] to homeostatic imbalances.”⁴ As a result, “this harmoniously operating neuroemotional system drives and energizes many mental complexities that humans experience as persistent feelings of interest, curiosity, sensation seeking, and, in the presence of a sufficiently complex cortex, the search for higher meaning.”^{4,p.145}

Panksepp explicitly rejects purely hedonistic reinforcement theories, characterizing the SEEKING system as *non-hedonistic* in nature: “This is a diametric reversal of traditional behaviorist thinking... The affective state [that serves as a motivator in some instances] is not simply ‘pleasure’ but a highly energized state of psychic power and engagement with the world.”^{4,pp.147-150}

While many biologists have emphasized the motivation to maintain predictability in one’s environment and routines,⁴⁶ there is also an innate drive to explore and discover previously unknown aspects of the environment, as every cat owner can attest. Cats desire predictability, but they crave balance between stability and the impulse for exploration and curiosity. This exploratory drive is part of Panksepp’s SEEKING system. Correlatively, Panksepp *et al.*⁶ found that clinical depression specifically involves a dysfunction or suppression of the SEEKING system. The reduction in feelings of inspiration or “enthusiasm” associated with SEEKING-system dysfunction—as though a cat were to lose its curiosity and zest for life—is reminiscent of Viktor Frankl’s notion that depression often arises from the feeling that one’s life “lacks meaning,” even when things appear objectively satisfactory. In Frankl’s framework, success in achieving superficial happiness is a separate dimension from experiencing meaningfulness in one’s trajectory of action. One of behaviorism’s key missteps was the conflation of these two motivational dimensions under the singular concept of “reinforcement.”

Antonio Damasio, in *The Feeling of What Happens*,¹² shows that when cortical brain areas are damaged, consciousness may persist (albeit with cognitive impairments). However, when deeper subcortical emotional structures are compromised, consciousness itself is lost. The deep subcortical structures support motivational and emotional patterns of brain functioning, which are crucial for the generation of purpose. They initiate larger patterns

of self-organizing activity that, in turn, activate further regions of the brain. Animal organisms do not merely react to environmental inputs; rather, they act out of internally generated, self-motivated organizational tendencies. The framework of self-organizing systems provides a conceptual basis for distinguishing self-motivated action from mere reactive behavior based on causal inputs.

Emotion and motivation reflect the self-organizational purposes of a living system. Motivation toward those purposes must already be in progress before perceptual content, let alone emotional content, can register in consciousness. Inattention blindness and change blindness experiments illustrate this point. In the above-mentioned Mack and Rock studies, subjects failed to consciously see objects to which they were not attending, and there is good evidence that motivational processes determine the direction of voluntary attention.¹⁴ In the case of voluntary attention (which is actually more common than involuntary attention), we attend to one thing rather than another because we want to. Even in the case of involuntary attention, RAS is already pre-set to be vigilant toward certain types of stimuli and not others,⁴⁷ as when a sailor on watch is attuned to noticing enemy submarines. Here again, the effects of emotion on RAS have been well documented, especially in cases of anxiety and depression.^{48,49}

The theory of self-organization provides a scientific basis for understanding how a system can be purpose-directed. In a self-organizing system, the system as a whole can reorganize its parts to compensate for disruptions of the holistic pattern of activity that characterizes the system. While micro-components at the molecular level follow regular laws of cause and effect, the system is continually rearranging the background conditions that those cause-and-effect mechanisms presuppose. This tendency allows the system to appropriate, replace, and repurpose the micro-components that constitute the system. Classic examples of this process can be found in the literature on recovery from stroke and other forms of localized brain damage.¹³ New brain cells can be repurposed to assume the functions of those that were destroyed—an entirely well-documented phenomenon.¹³ A simpler example is when we consume nutrients to replenish neurotransmitters necessary for the brain’s ongoing activity (i.e., when we eat). In foraging for food, the organism is literally seeking out and appropriating micro-components needed to sustain its activity. For example, without consuming foods containing the B vitamin choline, the brain would lack the crucial neurotransmitter acetylcholine.

We can observe the priority of motivational and emotional brain processes even in perception. When a

perceptual stimulus is presented, the timing of activation across brain areas can be measured using event-related potentials (ERPs). While less currently fashionable than functional magnetic resonance imaging (fMRI), ERPs offer far greater precision in tracking the temporal sequence of neural activations. ERPs are designated by a number, indicating the number of milliseconds since stimulus presentation, and a letter, P or N, indicating whether the potential is positive or negative. Conscious awareness of a visual object is typically observed at the P300 ERP in the parietal lobe (Figure 1). Visual processing in the occipital “visual areas” generally occurs between 100 and 200 ms after stimulus onset. However, emotional/motivational and action-initiating areas activate significantly earlier. The hippocampus activates at around 18 ms, and the cerebellum (where routinized action tendencies are stored) at 20 ms. The inhibitory functions of the frontal motor areas are already active between 100 and 200 ms, helping to suppress the action routines.⁵⁰ This inhibition is crucial for the formation of visual imagery. The following diagram illustrates the timing of activations across various brain areas. If the stimulus-response paradigm were valid, we would expect visual processing (in the occipital lobe) to occur first, followed by activation of emotional/

motivational areas, and then the action-initiating regions. However, this is not the sequence of activations observed in practice, as described below.

The timing of these ERPs suggests that motivational purposes, reflected in activity in emotional brain areas, are already in play before perceptual processing. We pay attention to environmental conditions relevant to these organismic purposes. When we encounter stimuli that saliently either facilitate (“afford”) or hinder our organismic motivations, the brain activates or inhibits motor, premotor, and cerebellar regions as needed to imagine or execute relevant actions. Only when the visual activity in the occipital area resonates with the “looking-for” intentionality of the attention system—as shaped by emotional and motivational processes—does the P300 ERP, corresponding to visual consciousness, occur. In this model, the motivated readiness for action precedes perceptual consciousness and guides it toward relevant inputs.

This timing is the reverse of what the stimulus-response paradigm generally presupposes. Emotion is not a reaction to the stimulus; on the contrary, the stimulus is attended to and processed, or not, according to whether and in what ways it is motivationally salient.

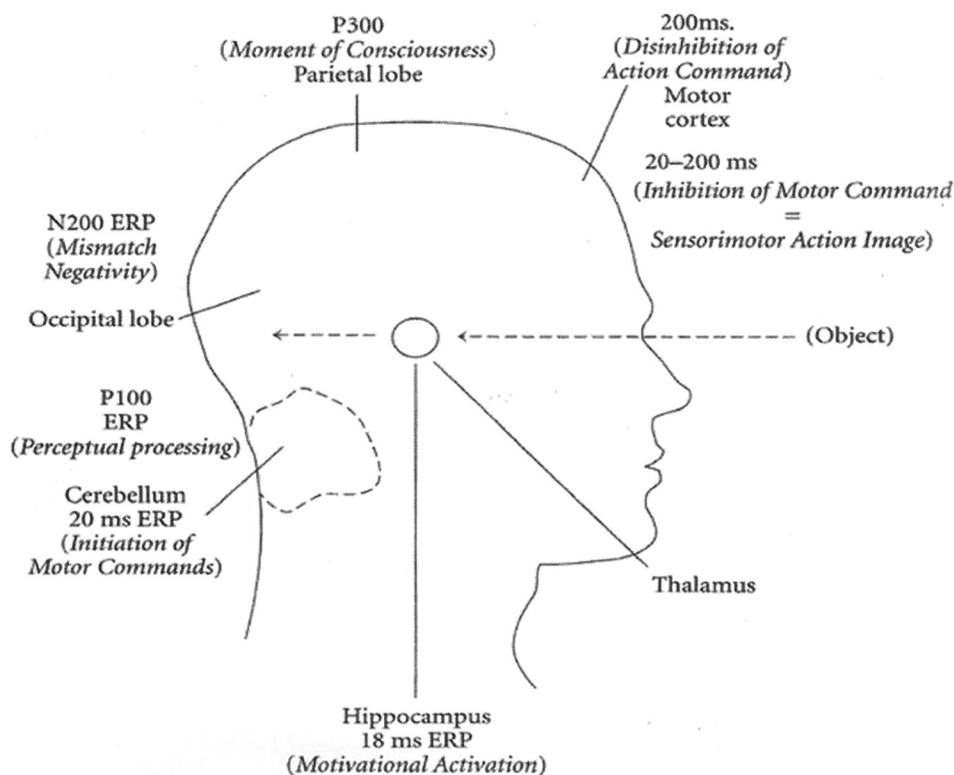


Figure 1. Sequence of brain activations in response to an unexpected stimulus
Abbreviation: ERP: Event-related potential.

An acting creature, as opposed to a merely reactive one, can understand its world by imagining possible actions that could or could not be executed relative to certain environmental affordances. This understanding of action affordances does not have to be conscious. Donoghue⁵¹ trained monkeys to play computer games by moving a joystick. He then strapped electrodes to their heads to pick up on the action commands being activated in the motor and premotor cortices of the monkeys. In the end, the monkeys were able to play the computer game “with their minds,” simply by imagining the needed actions. They were able to play the game without moving their hands because, as Jeannerod⁵² had already shown in 1997, when we imagine executing a given action, we activate most of the brain functions that would be needed to actually perform the action. The reason we are normally able to imagine an action without going through with it is that, after the action command has already been initiated at the cerebellar, motor, and premotor levels, the frontal brain areas continue to inhibit the signal from feeding forward to the body’s extremities. In effect, imagining the action is similar to actually doing the action, plus an extra ingredient: frontal inhibition. Eventually, the monkeys may be consciously thinking only of the computer game, without even moving their hands, but the neurophysiological picture shows that their brains are still subliminally activating the movement commands, while frontally inhibiting the signals from feeding forward to their hands. Jeannerod therefore argues that this is how we form “motor imagery.” The monkeys move gradually from conscious to unconscious motor imagery.

Gendlin^{53,54} argues that even perceptual awareness of the environment involves these subliminally inhibited action commands. If a musician, for example, imagines the sound of a musical melody by moving the fingers as if fingering an instrument, the imagination of the movement can usually occur “implicitly,” with no overt physical movement of the fingers. There is a gradation of degrees of subliminality in imagined “action affordances,” or, in Gendlin’s terms, the action affordances become “implicit.” Neurophysiology tells us that the inhibited motor representations are still occurring.

Action—in the sense of movement initiated by the organism (often without any stimulus trigger)—is not merely a complicated system of reactions. It must be motivated by the self-organizing processes of a living organism. For example, when an individual wakes in the morning and decides to go for a hike, no presently occurring external stimulus “causes” this action imagery. Damasio, Panksepp, Watt, and other neuropsychologists show that self-initiated actions presuppose motivational

processes that rely heavily on the brainstem, particularly the periaqueductal gray (PAG) and midbrain areas, which are heavily involved in emotion and motivation activation. The midbrain and PAG are especially important in activating the SEEKING system. All these same action-generating processes (as Jeannerod’s work shows) are also required even for the imagining of acting. Moreover, they, in turn, require emotional brain systems to motivate them. One of the most obvious differences between the brains of animals and the nuts and bolts of AI systems is that computers are not organized around these motivational processes. They are not self-organizing biological systems. The fact that they can be contrived to imitate human emotions should not distract us from this fundamental difference.

Given the way the brains of conscious beings such as humans are normally organized, we are inevitably driven to act in ways that are geared toward placing a value on certain outcomes. The intentionality of emotions, therefore, entails that we value some outcome, even if it is only the achievement of desired movements, as in the spontaneous play of young children and animals. As a result of Panksepp’s lifetime of research, he argues that there are a small number of independent and endogenous emotion systems in the brains of mammals, each with its own valued intentional goals and its own unique combination of brain areas and neurotransmitter systems. As can be seen from the following list, each endogenous emotion system uses its own unique combination of neurotransmitters and brain regions. If we count the PLEASURE/PAIN system, there are eight systems in all:

- (i) The SEEKING system energizes the body toward both consummatory and non-consummatory actions. This circuit includes the ventral tegmental area and the lateral hypothalamus; it relies heavily on neurotransmitters such as dopamine and glutamate, and it motivates behaviors that are active rather than passive responses to stimulation. It actively “seeks out” areas of interest in the environment and notably includes an “exploratory drive,” which in the 20th century tended to be relegated to a “secondary” or “derivative” reinforcer. On the contrary, it is endogenous in virtually all animals, and certainly in primates.

The SEEKING system is sometimes characterized as merely an “appetitive” system, but for Panksepp, it is clearly more than that—subserving curiosity, exploration for its own sake, and, more generally, the “will to live.” For example, in veterinary practice, when an elderly cat showed little interest in eating, treatment with mirtazapine not only stimulated appetite but also restored general vitality. The cat became energetic, playful, and curious, running around in

the yard and playing with the other cats. Neurochemically, mirtazapine stimulates the SEEKING system generally. When cats explore the environment, they are not exploring merely to find food or some other “reinforcer” as generally conceived. The exploratory behavior does not need to be conditioned, as if it were a secondary reinforcer. It results from normal brain development, which is biologically rooted.

- (ii) The RAGE system uses a unique combination of neurotransmitters and brain areas. It includes the medial amygdala, the bed nucleus of stria terminalis, and the medial hypothalamus (rather than the lateral hypothalamus emphasized in the SEEKING system), and importantly includes the PAG, emphasizing substance P and acetylcholine activity. Everyone is familiar with the effects of this system in the form of heart and circulatory problems that eventually develop when substance P is activated too frequently; the resulting excess of cortisol can lead to high blood pressure and hypertension. The RAGE system works in cooperation with the SEEKING system: we do not simply sit back and wait for something to activate RAGE as a stimulus-response mechanism. Instead, we seek out potential threats in the environment, and our attentional system is already tuned to a low-intensity state of vigilance. The advantages of having an endogenous tendency to become enraged in response to appropriate environmental affordances are clear. However, too much hyper-vigilance routinely leads to the physiological imbalances mentioned above, as well as counterproductive behavior. The Canadian neuroscientists Bush *et al.*⁵⁵ found that hyperactivation of the amygdala (a key component of the RAGE system) inhibits the functioning of the prefrontal cortex, which is needed for rational planning and thinking.
- (iii) The FEAR system includes the lateral amygdala, the medial hypothalamus, the PAG, and the pons, and it uses glutamate, monoamines, and numerous neuropeptides. It is well known that this system tends to hyperactivate the amygdala, leading to outcomes similar to those observed in the Bush study referenced earlier. Its activation releases corticotropin-releasing factor, which increases with stress and can eventually cause heart and circulatory problems, much like the effects of substance P in the RAGE system.
- (iv) The LUST system includes the PAG and the bed nucleus of the stria terminalis, as well as the cortico-medial amygdala and the ventromedial and preoptic hypothalamus. It uses vasopressin, oxytocin, and

steroids. Oxytocin fuels not only sexual lust but also the loving feelings of a mother toward her infant, doubling in quantity in the brain of a pregnant female to facilitate maternal bonding. It also plays a significant role in sexual behavior, increasing in the brains of both males and females immediately following sexual intercourse. Like the other endogenous emotion systems, LUST results from the natural biological development of the brain, not from reinforcement. As the role of oxytocin illustrates, LUST is closely interrelated with CARE (or nurturance).

- (v) The CARE (nurturance) system uses oxytocin, prolactin, dopamine, and opioids, and extends from the PAG and the bed nucleus of the stria terminalis to the ventral tegmental area, the anterior cingulate, and the preoptic areas. The increase in oxytocin during pregnancy is one of many empirical findings that demonstrate how this system undergirds nurturing and caring feelings. In Panksepp's view, it is an important component of the “fellow feeling” essential for social bonding and moral comportment. In fact, the CARE system, along with the SEPARATION DISTRESS system, creates a powerful need for social bonding and peer relationships in virtually all primates, including humans.
- (vi) The SEPARATION DISTRESS system (also called the PANIC system) shares with other emotion systems an emphasis on the PAG, but it also prominently involves the bed nucleus of the stria terminalis, the dorsomedial thalamus, and the preoptic hypothalamus. In humans and other primates, it also includes the anterior cingulate and anterior thalamus. It spreads activation and coordinates these brain areas through the use of opioids, corticotropin-releasing factor, and acetylcholine. It overlaps slightly with the LUST and CARE system by employing many of the same neurotransmitters. Note that for Panksepp, the term PANIC is distinct from FEAR, discussed above, as PANIC pertains specifically to social bonding emotions. When disrupted, these produce the intense PANIC reaction, especially in infants, in a mother separated from her infant, or in a mate or friend separated from a loved one. Here again, we see the survival advantages of this emotion system for the species, even though the individual organism may not experience pleasure or satiation from it.
- (vii) The PLAY system, extending from the posterior thalamus to the midbrain central gray and relying extensively on opioids and acetylcholine, is an

endogenous, unlearned system. The motivation for play is distinct from the motivation for pleasure, even though play often does lead to pleasant feelings. The independence of this system is evident when children or animals are reluctant to stop playing, even when physically exhausted, experiencing sore muscles or injuries, or when it is time to eat. For Panksepp, play is not merely a means to the end of some form of “pleasure;” rather, the behavior is its own reinforcement.

- (viii) The PLEASURE/PAIN system (in the sense of consummatory pleasure) relies extensively on opioids, regulated by gamma-aminobutyric acid, unlike the less “consummatory” SEEKING and PLAY systems. It extends from the medial hypothalamus (not the lateral hypothalamus, which is active in SEEKING) to the PAG.

The first seven systems in this list are not a result of reinforcement through pleasure and pain. All eight systems are endogenous. The PLEASURE/PAIN system has no special priority. Even if an animal is punished for exploring, it will still do so. The desire to explore the world is part of the exploratory drive, which is an aspect of the SEEKING system.

This new understanding of the neurobiology of emotion aligns more closely with the way phenomenologists have described lived emotional processes than with the older behaviorist paradigm. It avoids conflating the experience of a value—for example, the value of helping the poor—with mere happiness or pleasure, which may or may not arise depending on whether the valued outcome is successfully achieved. The intensification of the feeling of values *per se* is orchestrated by the endogenous brain systems studied by Panksepp and reflects the self-organizing nature of animal systems. The achievement of these values, when it occurs, may indeed be experienced as happiness or pleasure—the so-called “reinforcements” of behaviorism. However, whether or how intensely the values are felt in the first place is a separate emotional dimension. It is this dimension that suffers in clinical depression, as evidenced by suppressed SEEKING activity and intensified SEPARATION DISTRESS (or PANIC) activity. The role of SEEKING in clinical depression highlights the fact that emotional processes are oriented not only toward homeostasis, but also toward homeo-exstasis, manifest in curiosity, exploration, appetitive arousal, and, more generally, the “will to live.” This homeo-exstatic dimension was almost entirely absent from behaviorist and stimulus-response models of emotion. It reflects the reality that “far-from-equilibrium” basins of attraction are often preferred by complex, self-organizing systems.

5. Directions for future research and possible clinical applications

The connection between emotion, self-organization, and neuroplasticity across various cognitive processes is so extensive that the possibilities for clinical application and future research are almost endless.

From the standpoint of clinical practice, numerous streams of research and new ideas are already underway. We have already seen that there is a substantial body of research on brain recovery after trauma, but other applications are emerging as well. An illuminating example of the brain’s capacity to self-organize and change itself was demonstrated by Alfred Tomatis,^{56,57} who developed a method of re-training the ear to help individuals, especially singers, who had lost the ability to process certain frequency ranges. Tomatis had these individuals sing while listening through headphones to their voice, filtered so that only the problematic range was audible. Over time, their auditory systems and temporal lobes spontaneously readjusted, enabling them not only to hear the previously neglected frequency range but also to sing in it, after having lost that ability. Note that Tomatis is not making miraculous claims about an unlimited capacity for self-reorganization—he did not suggest, for instance, that deafness could be spontaneously cured through neuroplasticity. Dynamical systems can rearrange and replace their micro-constituents, but only within certain limits.

There are countless ways that a paradigm similar to Tomatis’s could be applied to help the brain reorganize itself by creating conditions that facilitate attention to neglected skills, thereby prompting self-regulated re-training. One promising area of research, among many, is the brain’s ability to remain flexible in old age. Norman Doidge⁵⁸ reports evidence that even the progression of Alzheimer’s disease can be slowed through techniques designed to enhance neuroplasticity and self-organization. However, we should not exaggerate the brain’s capacity for reorganization.

Importantly, the brain’s ability to reorganize itself through motivational control can have negative as well as positive consequences. The problem of addiction presents an opportunity to understand how the brain can reorganize itself around a habitual and destructive behavior. Doidge,⁵⁹ in his clinical work, describes cases where the SEEKING system appears to be co-opted by addiction. Using fMRI and other imaging techniques, he found evidence that the SEEKING system had been reorganized: it becomes generally dampened or constricted but remains active in relation to the addictive stimulus. Eventually, only the addictive behavior is

able to trigger the SEEKING system, and part of the “kick” of the addiction, in Doidge’s view, is that it allows the SEEKING system to express itself in ways unavailable in other contexts. His therapeutic approach involves redirecting SEEKING behavior toward alternative, non-addictive stimuli.^{58,p.71}

From the perspective of dynamical self-organizing systems, an addictive habit can be seen as a “basin of attraction.” Complex systems like the brain seek stable patterns of activity that maintain homeostasis. Any such pattern can become a basin of attraction in which the system settles. Doidge’s therapeutic efforts aim to help the brain settle into a different basin of attraction. One might view Alcoholics Anonymous as implicitly following a similar strategy: the social network of AA provides a new basin of attraction around which the brain can self-organize. This paradigm—viewing addiction as self-driven rather than stimulus-response—is still emerging and warrants further clinical and research exploration.

As previously discussed, numerous researchers have identified connections between emotional stress and various cognitive capacities, often focusing on the neurochemistry and cellular connections involved. Current studies also explore endogenously motivated gating functions of the RAS and other mechanisms for selection. Others investigate how motivation modulates neurotransmitters, which in turn influence different forms of cognitive functioning. The idea that emotion drives consciousness at all levels is illustrated by the work of Jang and Kwon, who, as mentioned earlier, show how consciousness itself is orchestrated by a specific chain of ascending neural pathways. Damasio had already shown that damage to cortical and even higher limbic areas impairs cognitive skills without necessarily eliminating consciousness. However, the lower the brain damage occurs, the more profound the loss of consciousness. Jang and Kwon are now working to break down the neural dynamics that explain why this is the case. Their findings again emphasize the role of motivation and emotion in driving the chain of neurotransmitter activity that enables conscious states and functions.

Given the central role of emotional and motivational processes in the self-organizing dynamics of the brain, future research will increasingly need to make use of ERPs in addition to the now-dominant fMRI, for two main reasons. First, fMRI measures brain activity through changes in blood flow. Because subcortical processes do not always produce significant changes in blood flow as cortical ones do, fMRI tends to be corticocentric. Second, while fMRI is excellent at localizing brain activity, it is far less precise in capturing timing, especially compared to ERP, which can detect neural events on a millisecond scale. Much of the discussion in this review regarding the

timing of brain events—and the precedence of emotion—relies on studies using ERP technology. If emotional brain areas drive self-organization, then ERP should play a more prominent role in future research.

Finally, numerous research programs have already begun to explore the neurochemistry of neuroplasticity at the cellular, synaptic, and connectivity levels. Many of these studies are increasingly attentive to the influence of emotion on neurochemical processes. Each of these research streams requires further development to clarify the specific neural substrates that support the self-organizing processes underlying neuroplasticity and the brain’s remarkable ability to change itself.

6. Conclusion

If the enactivist perspective is to be taken seriously, we should begin by acknowledging that every conscious act, and even every cognitive act below the level of consciousness, depends on activation of a prior motivational and emotional system. We must seek to understand the self-organizational neurochemistry that undergirds the streams of activation that not only gate perceptions but also engage widely extended brain areas, as guided by the motivational purposes and energy of the entire organism, for cognitive processes like perception to occur. As Merleau-Ponty puts it, we must look to see.

Especially important from a clinical standpoint is the recognition that emotions are endogenously driven, not merely mechanical reactions to external inputs. In terms of real-life emotional awareness, this means that emotions often are not about what they appear to be about. The trigger for an emotion can be understood as an affordance or a blockage offered by the environment with respect to the organism’s endogenously self-organized action tendencies, as reflected in Panksepp’s emotion systems. Even as Panksepp’s approach is revised and expanded, perhaps to account for the greater malleability of endogenous motivational tendencies under environmental and developmental influence, the basic framework of motivation as serving the self-organizational purposes of the whole organism must remain. These purposes go beyond the pleasure-pain dynamics of earlier motivational theories. We are motivated to take certain kinds of actions that express the patterns of activity forming “basins of attraction” in the complex dynamical systems of our species. Environmental affordances do not cause these emotions; rather, the emotions find occasions to express themselves relative to the environment.

With regard to the interpersonal environment, those relations are more than mere conveniences facilitating individual self-organization. Several of Panksepp’s emotion systems exist precisely because they reflect

the fact that, as Gendlin puts it, we are not simply in relation to our environment—we are those relations. Systems like PANIC (SEPARATION DISTRESS), CARE (NURTURING), PLAY, FEAR, and RAGE reflect the inevitable embeddedness of our kind of organism in social relations. A seemingly trivial insult or the rejection of a job application can disturb any or all of these endogenously motivated emotion systems, not because the insult or rejection is intrinsically significant, but because such events resonate with our basic motivational purposes and life trajectory. These experiences are ultimately about our ongoing efforts to remain motivated and to locate values worth striving for, as reflected in the SEEKING system.

Theories of dynamical systems and enaction have only recently begun to make substantial inroads into the study of consciousness and cognition, let alone into clinical practice. Only toward the end of the 20th century did mainstream cognitive theorists begin to seriously distinguish between conscious and non-conscious forms of information processing. This change has inaugurated a major shift in the way we understand the dynamics of the brain, the motivational architecture of organisms, and their embeddedness in environmental contexts. The impact of self-organizational approaches is already being felt in cognitive theory, particularly in the investigation of neuroplasticity and its emotional underpinnings, both physiological and phenomenological. This review has only scratched the surface of the growing body of research, which will no doubt yield increasingly valuable insights in the years to come.

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References

1. McEwen BS, Sapolsky RM. Stress and cognitive function. *Curr Opin Neurobiol.* 1995;5(2):205-216.
doi: 10.1016/0959-4388(95)80028-x
2. Shors TJ, SeibTB, Levine S, Thompson RF. Inescapable versus escapable shock affects long-term potentiation in the rat hippocampus. *Science.* 1989;244:224-226.
doi: 10.1126/science.2704997
3. McEwen B, Nasca C, Gray J. Stress effects on neuronal structure: Hippocampus, amygdala and prefrontal cortex. *Neuropsychopharmacol.* 2016;41:3-23.
doi: 10.1038/npp.2015.171
4. Panksepp J. *Affective Neuroscience.* New York: Oxford University Press; 1998.
5. Panksepp J. The neuro-evolutionary cusp between emotions and cognitions: Implications for understanding consciousness and the emergence of a unified mind science. *Conscious Emot.* 2000;1(1):15-54.
doi: 10.1075/ce.1.1.04pan
6. Panksepp J, Wright JS, Döbrössy MD, Schlaepfer TE, Coenen VA. Affective neuroscience strategies for understanding and treating depression: From preclinical models to three novel therapeutics. *Clin Psychol Sci.* 2014;2(4):472-494.
7. Watt DE. The separation distress hypothesis of depression - an update and systematic overview. *Neuropsychanalysis.* 2023;25(2):103-159.
doi: 10.1080/15294145.2023.2240340
8. Aurell CG. Perception: A model comprising two modes of consciousness. Addendum: Evidence based on event-related potentials and brain lesions. *Percept Motor Skills.* 1983;56:211-220.
9. Aurell CG. Perception: A model comprising two modes of consciousness. Addendum II: Emotion incorporated. *Percept Motor Skills.* 1984;59:180-182.
doi: 10.2466/pms.1984.59.1.180
10. Aurell CG. Man's triune conscious mind. *Perceptual Motor Skills.* 1989;68:747-754.
11. Chalmers D. Facing up to the problem of consciousness. *J Conscious Stud.* 1995;2:200-219.

12. Damasio A. *The Feeling of What Happens*. New York: Harcourt Brace; 1999.
13. Ellis RD. *Curious Emotions: Roots of Consciousness and Personality in Motivated Action*. Amsterdam: John Benjamins; 2005.
14. Ellis RD. *Questioning Consciousness*. Amsterdam: John Benjamins; 1995.
15. Kelso JA. *Dynamic Patterns: The Self-organization of Brain and Behavior*. Cambridge, Massachusetts: MIT/Bradford; 1995.
16. Ellis R, Newton N. *How the Mind Uses the Brain*. Chicago: Open Court; 2010.
17. Ellis RD. *Action, Embodied Mind, and Life-World: Focusing at the Existential Level*. Stonybrook, NY: SUNY Press; 2024.
18. Ellis RD. *The moral psychology of internal conflict: Value, meaning, and the enactive mind*. Cambridge University Press; 2018.
doi: 10.1017/9781316996683
19. Kauffman S. *The Origins of Order*. Oxford: Oxford University Press; 1993.
20. Merleau-Ponty M. *Phenomenology of Perception*. New York: Humanities Press; 1941/1962.
21. Merleau-Ponty M. *The Structure of Behavior*. Boston: Beacon; 1942/1963.
22. Shors TJ. Stressful experience and learning across the lifespan. *Annu Rev Psychol*. 2006;57:55-85.
doi: 10.1146/annurev.psych.57.102904.190205
23. Panksepp J. In defense of multiple core affects. In: Zachar P, Ellis R, editors. *Categorical Versus Dimensional Approaches to Emotion*. Amsterdam: John Benjamins; 2012.
24. Ahmed T, Frey JU, Korz V. Long-term effects of brief acute stress on cellular signaling and hippocampal LTP. *J Neurosci*. 2006;26: 3951-3958.
doi: 10.1523/JNEUROSCI.4901-05.2006
25. Banasr M, Valentine GW, Li XY, Gourley S, Taylor J, Duman RS. Chronic stress decreases cell proliferation in adult cerebral cortex of rat: Reversal by antidepressant treatment. *Biol Psych*. 2007;62:496-504.
26. Cook SC, Wellman CL. Chronic stress alters dendritic morphology in rat medial prefrontal cortex. *J Neurobiol*. 2004;60:236-248.
doi: 10.1002/neu.20025
27. Bavelier D, Levi DM, Li RW, Dan Y, Hensch TK. Removing brakes on adult brain plasticity: From molecular to behavioral interventions. *J Neurosci*. 2010;30(45):14964-14971.
doi: 10.1523/jneurosci.4812-10.2010
28. Holzel BK, Carmody J, Evans KC, et al. Stress reduction correlates with structural changes in the amygdala. *Soc Cogn Affect Neurosci*. 2010;5:11-17.
doi: 10.1093/scan/nsp034
29. Lakshminarasimhan H, Chattarji S. Stress leads to contrasting effects on the levels of brain derived neurotrophic factor in the hippocampus and amygdala. *PLoS One*. 2012;7(1):e30481.
doi: 10.1371/journal.pone.0030481
30. Karatsoreos IN, Bhagat S, Bloss EB, Morrison JH, McEwen BS. Disruption of circadian clocks has ramifications for metabolism, brain, and behavior. *Proc Natl Acad Sci U S A*. 2011;108:1657-1662.
doi: 10.1073/pnas.1018375108
31. Liston C, Cichon JM, Jeanneteau F, Jia Z, Chao MV, Gan WB. Circadian glucocorticoid oscillations promote learning-dependent synapse formation and maintenance. *Nat Neurosci*. 2013;16(6):698-705.
doi: 10.1038/nn.3387
32. Brydges NM, Jin R, Seckl J, Holmes MC, Drake AJ, Hall J. Juvenile stress enhances anxiety and alters corticosteroid receptor expression in adulthood. *Brain Behav*. 2014;4(1):4-13.
doi: 10.1002/brb3.182
33. Bessa JM, Ferreira D, Melo I, et al. The mood-improving actions of antidepressants do not depend on neurogenesis but are associated with neuronal remodeling. *Mol Psychiatry*. 2008;14:764-773.
doi: 10.1038/mp.2008.119
34. Wolpaw JR. Harnessing neuroplasticity for clinical applications. *Brain*. 2012;135(4):e215.
doi: 10.1093/brain/aws017
35. Hill MN, McLaughlin RJ, Pan B, et al. Recruitment of prefrontal cortical endocannabinoid signaling by glucocorticoids contributes to termination of the stress response. *J Neurosci*. 2011;31:10506-10515.
doi: 10.1523/jneurosci.0496-11.2011
36. Jang SH, Kwon HG. The direct pathway from the brainstem reticular formation to the cerebral cortex in the ascending reticular activating system: A diffusion tensor imaging study. *Neurosci Lett*. 2015;606:200-203.
doi: 10.1016/j.neulet.2015.09.004
37. Gibson JJ. *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin; 1979.
38. Hurley S, Noë A. Neural plasticity and consciousness. *Biol Philos*. 2003;18:131-168.
doi: 10.1023/a:1023308401356
39. Di Paolo EA. Autopoiesis, adaptivity, teleology, agency. *Phenomenol Cogn Sci*. 2005;4:429-452.
doi: 10.1007/s11097-005-9002-y
40. Colombetti G. *The Feeling Body: Affective Science Meets the Enactive Mind*. Cambridge, MA: MIT Press; 2014.

41. Fuchs T. *Ecology of the Brain: The Phenomenology and Biology of the Embodied Mind*. New York: Oxford University Press; 2018.
42. Mack A, Rock I. *Inattentional Blindness*. Cambridge: MIT/Bradford; 1998.
43. Abrahamson D, SS, Bakker A, Van der Schaaf M. Eye-tracking piaget: Capturing the emergence of attentional anchors in the coordination of proportional motor action. *Hum Dev*. 2016;58(4-5):218-244.
doi: 10.1159/000443153
44. De Jaegher H, Pieper B, Clénin, D, Fuchs, T. Grasping intersubjectivity: An Invitation to embody social interaction research. *Phenomenol Cogn Sci*. 2017;16(3):491-523.
doi: 10.1007/s11097-016-9469-8
45. Gallagher S. Enactivism, causality, and therapy. *Philos Psychiatry Psychol*. 2020;27(1):27-28.
doi: 10.1353/ppp.2020.0002
46. Bitbol M. Neurophenomenology of surprise. In: Depraz N, Celle A, editors. *Surprise at the Intersection of Phenomenology and Linguistics*. Amsterdam: John Benjamins; 2019.
47. Wang N, Perkins E, Zhou L, Warren S, May PJ. Reticular formation connections underlying horizontal gaze: The central mesencephalic reticular formation (cMRF) as a conduit for the collicular saccade signal. *Front Neuroanat*. 2017;11:36.
doi: 10.3389/fnana.2017.00036
48. Stone E, Lin Y, Rosengarten H, Kramer HK, Quartermain D. Emerging evidence for a central epinephrine-innervated α_1 -adrenergic system that regulates behavioral activation and is impaired in depression. *Neuropsychopharmacology*. 2003;28:1387-1399.
doi: 10.1038/sj.npp.1300222
49. Benghanem S, Mazeraud A, Azabou E. Brainstem dysfunction in critically ill patients. *Crit Care*. 2020;24(5):5.
doi: 10.1186/s13054-019-2718-9
50. Maier M, Ballester BR, Verschure PFMJ. Principles of neurorehabilitation after stroke based on motor learning and brain plasticity mechanisms. *Front Syst Neurosci*. 2019; 3:74.
51. Donoghue JP. Connecting cortex to machines: Recent advances in brain interface. *Nature Neurosci Suppl*. 2002;5:1085-8.
doi: 10.1038/nn947
52. Jeannerod M. *The Cognitive Neuroscience of Action*. Oxford: Blackwell; 1997.
53. Gendlin E. *A Process Model*. Evanston: Northwestern University Press; 2017.
54. Gendlin ET. *Saying What We Mean*. Evanston: Northwestern University Press; 2018.
doi: 10.2307/j.ctv7tq4qc
55. Bush, G, Luu P, Posner M. Cognitive and emotional influences in anterior cingulate cortex. *Trends Cogn Sci*. 2000;4(6):215-222.
doi: 10.1016/s1364-6613(00)01483-2
56. Tomatis AA. *The Conscious Ear: My Life of Transformation through Listening*. Barrytown, NY: Station Hill Press; 1991.
57. Tomatis AA. *The Ear and the Voice*. Lanham, MD: Rowman and Littlefield; 2004.
58. Doidge N. *The Brain's Way of Healing*. New York: Penguin; 2016.
59. Doidge N. *The Brain that Changes Itself*. New York: Penguin; 2016. p. 104-112.