Chapter 5
States Of Consciousness

States of Consciousness Introduction

Mind in nature is a property of particular brains with particular histories; that is, of particular phenotypes with particular brain areas and structures capable of the kind of memory that leads to consciousness.

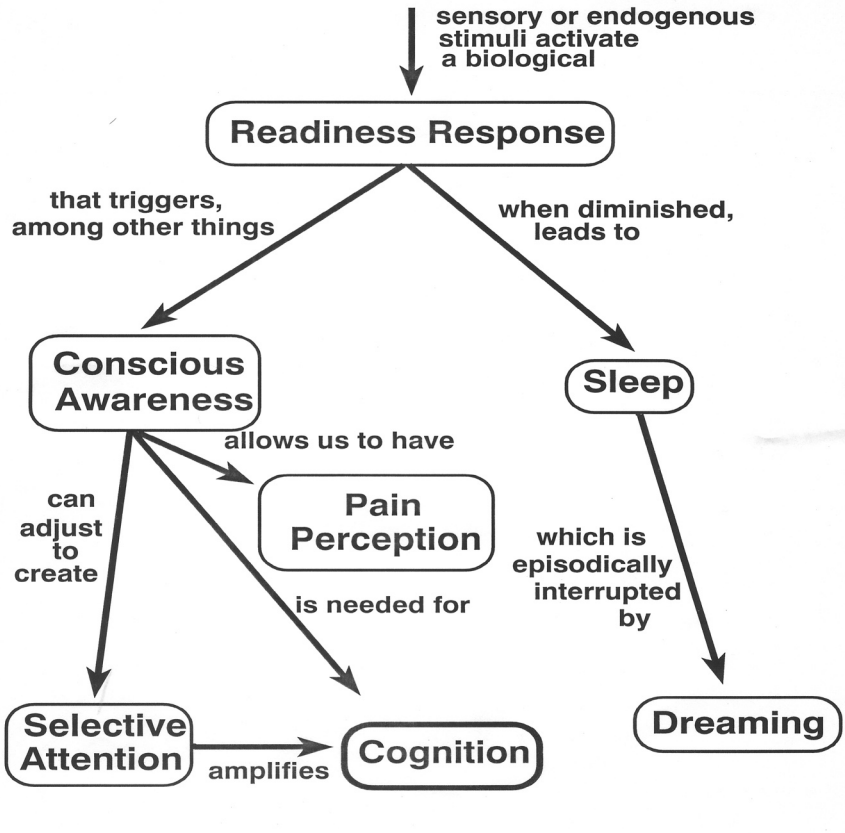
— George Edelman

To say that consciousness is a state of mind begs the question of what is mind? We know there is also unconscious mind. So maybe it helps to think of mind as an abstract representation of the sum total of what is going on in the brain. As for conscious mind, we don't really know what that is, but from our own introspection we know it when we experience it. It is not enough to say that consciousness is a state of awareness. Even a lowly amoeba is aware, in some primitive sense, when it bumps into a noxious chemical. So consciousness must include the idea of being aware that awareness is present.

We know that consciousness is related to many common experiences: for example, attentiveness, thinking, pain, sleeping, and dreaming.

At the core of the mechanisms of various states of consciousness is what we might call a **Readiness Response**, which is a global brain and body activation produced by biologically significant stimuli, either exogenous or endogenous. As part of this brain activation, **Conscious Awareness** occurs, at least in higher animals. Awareness can be fo-

cused to produce **Selective Attention**. Conscious, selective attention of our inner and outer worlds is the basis for human **Cognition**, that unique human ability to think about past, present, and future.



Concept map of the various states of consciousness.

Conscious awareness is also what enables us to have **Pain Perception**, which is a response to noxious stimuli that not only causes us to avoid such stimuli, but which produces a feeling that can only be registered consciously.

When the tonic excitatory drive that actives the brain diminishes, the brain can enter the state of unconsciousness and body quiescence that we call **Sleep**. At various times during sleep, the brain state can be interrupted to convert into a unique state that enables **Dreaming**.

Ideas in This Category:

Readiness Response
Conscious Awareness
Selective Attention
Cognition
Pain Perception
Sleep
Dreaming

List of Ideas

Readiness Response

Widespread populations of neurons in the brainstem govern the responsiveness to sensory input, the state of consciousness and alertness, activation of many visceral and emotive systems, the tone of postural muscles, and the orchestration of primitive and locomotor reflexes. The brainstem mobilizes a host of sensory, motor, and visceral responses to biologically significant stimuli to produce a generalized "readiness response."

Conscious Awareness

In humans, at least, the nervous system is aware of some of what it is aware of. That is, it "knows that it knows." This state is created, perhaps as an emergent property, by the interaction of the cerebral cortex and the brainstem reticular formation.

Consciousness and perception are mutually implicated. There is no consciousness without perception and no perception without consciousness. Similar mutual implications exist with consciousness and other mental states, such as beliefs and intentions.

Selective Attention

Attentiveness to stimuli or situational context is selective and involves multiple interdependent, activated neuronal populations. Each area may make its own contribution the stimulus or situation analysis. Because real-world stimuli and situations comprise much more information than the nervous system can accommodate, the brain adapts to this sensory overload by selectively attending at any given moment to only a small sub-set of the stimulus/situation and then distributing an appropriate abstracted output to appropriate output targets. Past learning helps the nervous system to "decide" which features of the stimulus or situation are most salient.

Cognition

Cognition (which may loosely regard as thinking) occurs in multiple brain areas, wherein each area makes its contribution to the analysis or task, yet each area is dependent on the others. The cognitive process involves local computation in parallel, distributed sites, followed by re-entrant or delayed inputs back into those local process areas. The process depends on conscious awareness, is amplified by selective attention, is plastic, and involves progressive recruitment over time of other local areas.

Pain Perception

Pain is a sensory perception that occurs in the consciousness. Several neural influences regulate pain threshold. Neuronal connectivity ambiguities can distort the perception of pain.

Sleep

Sleep is a behavioral quiescence, generally presumed to produce rest. In higher animals, sleep is more than just quiescence, with special neural

functions that generate and sustain it, along with characteristic neurophysiological changes.

Dreaming

Dreaming is a unique stage of sleep in which the brain creates its own inner consciousness that is disconnected from awareness of events in the external world. The brain is activated and produces physiological signs that are quite distinct from ordinary sleep.

Readiness Response

Core Idea

Widespread populations of neurons in the brainstem govern the responsiveness to sensory input, the state of consciousness and alertness, activation of many visceral and emotive sytems, the tone of postural muscles, and the orchestration of primitive and locomotor reflexes. The brainstem mobilizes a host of sensory, motor, and visceral responses to biologically significant stimuli to produce a generalized "readiness response."

Terms

affect (noun) — more or less equivalent to emotions. A term that is often reserved for animals, in order to seem less anthropomorphic.

autonomic nervous system — that subdivision of the nervous system that regulates (unconsciously) visceral activities. This includes regulation of the cardiovascular, respiratory, and digestive systems.

brainstem — that part of the brain that is interposed between the spinal cord and the forebrain. It is generally considered to include the medulla, pons, midbrain, and some people would also include the hypothalamus.

EEG (electroencephalogram) — electrical potentials recorded from a population of neurons, typically recorded from electrodes placed on the scalp.

limbic system — a collection of neuronal groups in the brain that collectively act to govern emotions. Important structural areas include the hypothalamus, hippocampus, septum, amygdala, and parts of the

cerebral cortex (cingulate, piriform, entorhinal).

periaqueductal grey — the brainstem has a central canal ("aqueduct") that contains cerebrospinal fluid. The pool of neurons immediately surrounding this canal is called the periaqueductal grey. It is also known as the central grey.

reticular formation — a massive collection of neurons in the central core of the brainstem. Many of these neurons are small with only local interactions, while others have long ascending and descending fiber projections.

thalamus — a mass of neuronal clusters along the midline of the brain, lying underneath the cerebral cortex. Many of these neuronal clusters are topographically mapped specific sensory pathways. Here, we are talking about the reticular portion of the thalamus, which is the anterior extension of the brainstem reticular formation. This part of the thalamus projects nonspecifically to widespread areas of the cortex.

Explanation

Various populations of neurons in the brainstem are nodal points between sensory input and motor output. These populations govern the responsiveness to sensory input, the state of consciousness and alertness, activation of many visceral and emotive systems, the tone of postural muscles, and the orchestration of primitive and locomotor reflexes. Collectively, these effects permit an adaptive response to biologically significant stimuli — in short, a "readiness response."Activation of the brainstem, particularly the reticular formation and periaqueductal grey, is seen to engage a constellation of sensory, integrative, and motor responses for adaptive response to novel or intense stimuli. Also engaged during activation are brainstem nuclei whose neurons release specific neurotransmitters: raphe (serotonin), locus ceruleus (norepinephrine),

and substantia nigra (dopamine).

We can think of a readiness response as including behavioral and mental arousal. When the animal is aroused by sensory input, all relevant systems are activated by reflex action. Behavioral readiness is a state of preparedness for making appropriate behavioral responses to environmental contingencies. The brainstem, particularly its reticular formation, has long been accepted as mediating such components of readiness as arousal and orienting. The brainstem also mediates most of the other components of readiness by generating a global mobilization that includes enhanced capability for selective attention, cognition, affect, learning and memory, defense, flight, attack, pain control, sensory perception, autonomic "fight or flight," neuroendocrine stress responses, visuomotor and vestibular reflexes, muscle and postural tone, and locomotion.

In a readiness response, the cerebral cortex is excited, enhancing consciousness and arousal level. Concurrently, muscle tone is enhanced, preparing the body for forthcoming movement instructions. Simultaneously, the limbic system is activated, which allows new stimuli to be evaluated in the context of memories. Also at the same time, neurons of the hypothalamus and the autonomic nervous system mobilize the heart and other visceral organs for the so-called fight-or-flight situations. This conglomeration of responses makes an animal ready to respond rapidly and vigorously to biologically significant stimuli. These multiple reflex-like responses are for the most part very obvious during startle reactions of either animals or humans. Less intense stimuli may not evoke a full-blown readiness reflex because the brain can quickly determine whether or not a response of great intensity is appropriate to the stimuli.

Brainstem reticular formation (BSRF) cells receive collateral sensory inputs from all levels of the spinal cord, including such diverse sources as cutaneous receptors of the body and head, Golgi tendon organs, aortic and carotid sinuses, several cranial nerves, olfactory organs, eyes, and ears, in addition to extensive inputs from other brainstem areas, the cerebellum, and the cerebral cortex. Thus, the BSRF is ideally situated to monitor and respond to a variety of stimuli that can be

biologically significant.

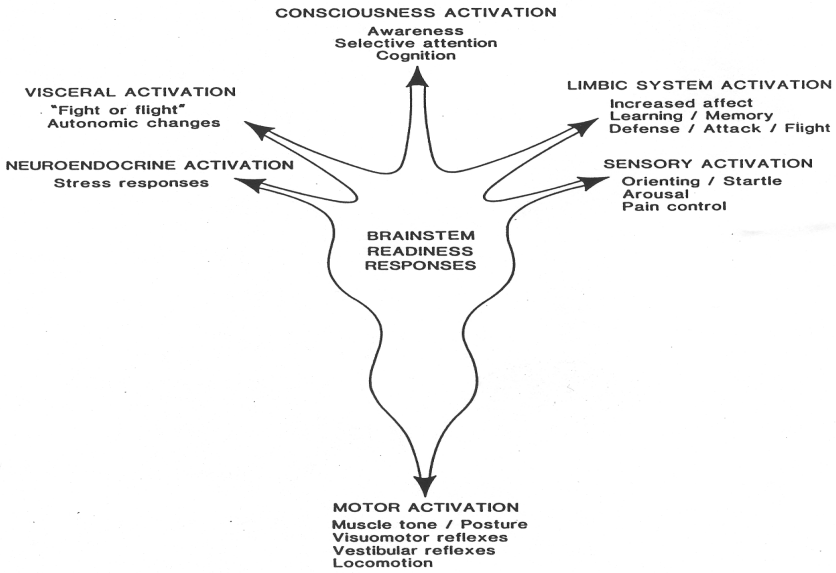


Diagram of the physiological components of the readiness response.

When BSRF neurons are stimulated by sensory input of any kind, they relay excitation through numerous reticular synapses and finally activate widespread zones of the cerebral cortex. In contrast, sensory information that arrives in the cortex via the main sensory paths passes through relatively few synapses and arrives at specific and very discrete zones of the cortex.

The BSRF responds in similar ways to any sensory stimulus, whether from the skin, eyes, ears, or whatever, to "awaken" the cerebral cortex so that it can respond to and process stimuli.

While the obvious conclusion is that the reticular formation creates arousal by direct excitation of higher centers, one cannot yet rule out the possibility that the excitation is indirect and results from a release from inhibition.

Examples

Some components of the readiness response are more evident than others. Consider orienting. If you hear a sudden, loud noise, most likely you will reflexly turn your head toward the sound and become tense. You may not be aware of many visceral changes that also occur, such as an immediate rise in pulse rate and blood pressure.

Another good example to which most people can relate is found in a sleeping cat who is suddenly startled into arousal by a dog barking nearby. The cat leaps to its feet, orients to the dog, becomes extremely tense (including arching of the back and extension of the limbs). The hair will rise and the cat will hiss and prepare to lash out its claws toward the dog. Clearly, the cat is mobilized for total body response to the threat.

One reason that the readiness response is a total body response is that the BSRF gets extensive input from various brain regions, particularly the neocortex and limbic system. Such input can be a major influence on behavior. For example, the cortical and limbic-system activities that are associated with the distress of a newly weaned puppy probably supply a continuous barrage of impulses to the BSRF, which in turn continually excites the cortex to keep the pup awake and howling all night.

The role of the BSRF in these arousing responses can be demonstrated by direct electrical stimulation at many points within the brainstem reticulum. Such stimulation activates the neocortex (indicated by LVFA in the EEG), the limbic system (rhythmic theta activity in the hippocampus), and postural tone (increased electrical activity of muscles). Additionally, many visceral activities are activated via spread of BSRF excitation into the hypothalamus.

All readiness response components seem to be triggered from the BSRF, the central core of the brainstem. Evidence that the BSRF performs an important function in readiness includes: (1) humans with lesions in the BSRF area are lethargic or even comatose, (2) surgical isolation of the forebrain of experimental animals causes the cortex to

generate an EEG resembling that seen in sleep. 3) Direct electrical stimulation of the BSRF has unique abilities to awaken sleeping animals and to cause hyperarousal in awake animals. (4) BSRF neurons develop a sustained increase in discharge just before behavioral and EEG signs of arousal.

Some recent studies have implicated cholinergic neurons in the pons in the EEG arousal component of the readiness response. These neurons appear to be under tonic inhibitory control of adenosine, a neuromodulator that is released during brain metabolism. This may relate to the mental stimulating properties of caffeine and theophylline, which act by blocking adenosine receptors.

Related Ideas

Conscious Awareness
Neurotransmission (Cell Biology)
Neurohormonal Control (Overview)
Pain Perception
Receptive fields (Senses)
Selective Attention
Reflex Action (Information Processing)

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