



Biological Basis of Emotions

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Abstract

This is an in-depth article on the basis of emotions. It is beyond the scope of the Human Factors: Error & Threat Management Course but is provided for those interested in understanding the structures of the brain that control emotions. During classes students often ask about “emotions run wild.” While it may be a “touch” academic, I hope you find it enlightening. I have attempted to simplify medical terminology for ease of reading.

As you will see emotions are extremely complex and affected by many things. Emotion and mood changes resulting from drugs, alcohol, and injury are easier to understand than depression and paranoia. All of us have seen emotional changes in ourselves and our loved ones and have wondered what was going on. I hope this article gives you more insight into the complexities of the brain and its role in emotion.



Introduction: The Three Units of the Human Brain

Throughout its evolution, the human brain has acquired three components that progressively appeared and became superimposed in the brain, just like in an



archeological site: The oldest (reptilian brain), is located underneath and to the back; the next one (old mammalian brain), rests on an intermediate position and the most recent (rational brain), is situated on top and to the front. They are, respectively:

1. The archipallium or primitive (reptilian) brain comprises the structures of the brain stem. It corresponds to the reptile brain, also called "R-complex", by the famous neuroscientist Paul MacLean.
2. The paleopallium or intermediate (old mammalian) brain, comprises the structures of the limbic system. It corresponds to the brain of the inferior mammals.
3. The neopallium, also known as the superior or rational (new mammalian) brain, comprises almost the whole of the cerebral hemispheres. It corresponds to the brain of the superior mammals, thus including the primates and, consequently, the human species.

These three cerebral layers appeared one after the other, during the development of the embryo and the fetus, and reflect chronologically, the evolution of animal species, from the lizards up to the homo sapiens. The layers are three separate biological



computers which, although interconnected, retain their own peculiar types of intelligence, subjectivity, sense of time and space, memory, mobility, and other less specific functions.

Reptilian Brain: The primitive (reptilian) brain is responsible for self preservation. It is there that the mechanisms of aggression and repetitive behavior are developed. It is there that occur the instinctive reactions of the so-called reflex arcs and the commands which allow some involuntary actions and the control of certain visceral functions (cardiac, pulmonary, intestinal, etc), indispensable to the preservation of life. It is also the center for approach, attack, flight, flight, and mating behavior. It is also in the R-complex that started the first manifestations of the phenomena of ritualism, by means of which the animal tries to define its hierarchic position inside the group and to establish its own space in the ecological niche.

Old Mammalian Brain: Right underneath the cortex, there exists an area known as the limbic lobe (from the Latin word "limbus" that implies the idea of a circle, or ring, or surrounding, since it forms a kind of border around the brain stem. This structure developed with the emergence of the inferior (primitive) mammals. This system commands certain behaviors that are necessary for the survival of all mammals. It gives rise and controls specific functions that allow the animal to distinguish between the agreeable and the disagreeable. Here specific emotional functions are developed, such as the one that induces the females to nurse and protect their toddlers, or the one which induces these animals to develop playful moods. Emotions and feelings, like wrath, fright, passion, love, hate, joy and sadness, are mammalian inventions, originating in the limbic system. This system is also responsible for some aspects of personal identity and for important functions related to memory.

Rational Brain: When the superior mammals appeared on the earth, the third cerebral unit was finally developed, the rational brain. This is a highly complex net of neural cells capable of producing a symbolic language, thus enabling man to exercise skillful intellectual tasks such as reading, writing and performing mathematical calculations. The rational brain is the great generator of ideas.



Theories on the Role of Brain Structures in the Formation of Emotions

There have been many theories on how human emotions are formed. We have arrived at the point where most researchers believe that emotion is not a function of any specific brain center but of a circuit that involves four basic structures, interconnected through several nervous bundles: the hypothalamus with its attached components, the anterior thalamic nucleus, the cingulate gyrus and the hippocampus.

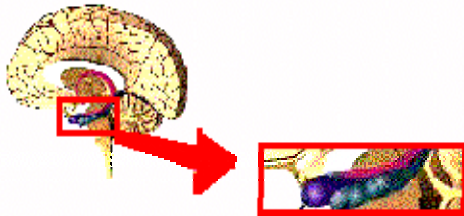
These structures form a circuit (Papez circuit), acting in a harmonic fashion, which is responsible for the central functions of emotion (affect), as well as for its peripheral expressions (symptoms).

Following is a discussion of each of the areas that play a role in emotions. As you will see this is not a simple process but one of extreme complexity as the systems communicate and work together.

The Main Areas Involved with Emotions

It is important to stress that all these structures interconnect intensively and none of them is the sole responsible for any specific emotional state. However, some contribute more than others to this or that kind of emotion. We shall review now, one by one, the best known structures of the limbic system.

Amygdala and Hippocampus



Amygdala

A little almond shaped structure, deep inside the temporal lobe, connects with the hippocampus, and other critical structures of the brain. These connections make it possible for the amygdala to play its important role on the mediation and control of major affective activities like friendship, love and affection, on the expression of mood and, mainly, on fear, rage and aggression. The amygdala, being the center for identification of danger, is fundamental for self preservation. When triggered, it gives rise to fear and anxiety which lead the animal into a stage of alertness, getting ready to flight or flee. Experimental destruction of both amygdalas (there are two of them, one in each hemisphere) tames the animal, which becomes sexually non-discriminative, deprived of affection and indifferent to danger. The electrical stimulus of these structures elicits crises of violent aggressiveness. Humans with marked lesions of the

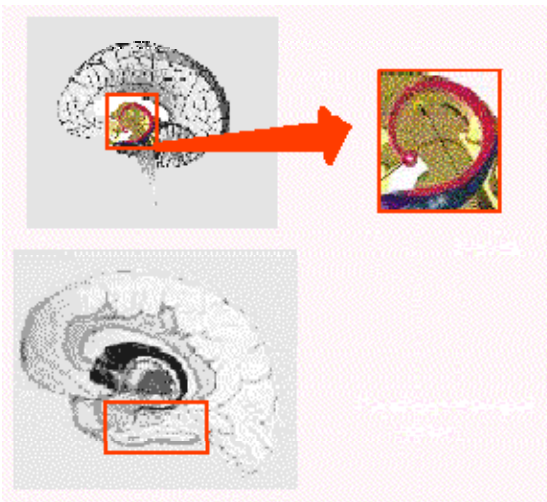


amygdala, lose the affective meaning of the perception of outside information, like the sight of a well known person. The subject knows, exactly, who the person is, but is not capable to decide whether he likes or dislikes him (or her).

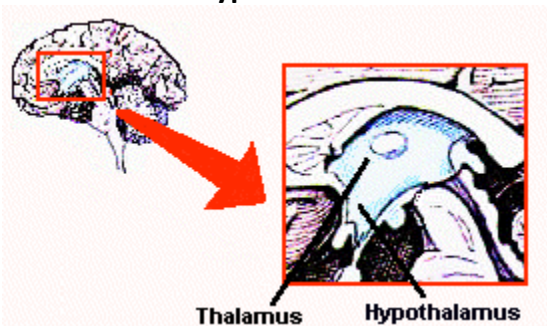
Hippocampus

This structure is particularly involved with memory phenomena, especially with the formation of long-term memory (the one that, sometimes, lasts forever). When both sides of the hippocampus are destroyed, nothing can be retained in the memory. The subject quickly forgets any recently received message. The intact hippocampus allows the animal to compare the conditions of a present threat with similar past experiences, thus enabling it to choose the best option, in order to guarantee its own survival.

Fornix and Parahippocampal Gyrus: These are important connecting pathways of the limbic system.



Thalamus and Hypothalamus





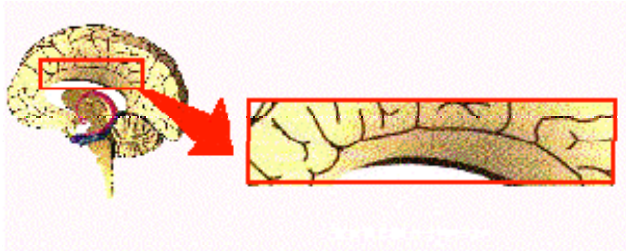
Thalamus

Lesion or stimulation of the thalamus is associated with changes in emotional reactivity. However, the importance of the thalamus on the regulation of emotional behavior is not due to the thalamus itself, but to the connections of with other limbic system structures. The thalamus makes connections with the cerebral cortex and with the hypothalamus and with other critical structures in the Papez's circuit.

Hypothalamus

This structure has ample connections with the other structures. Lesions of the hypothalamic nuclei interfere with several vegetative functions and some of the so-called motivated behaviors, like thermal regulation, sexuality, combativeness, hunger and thirst. The hypothalamus is also believed to play a role in emotion. Specifically, its lateral parts seem to be involved with pleasure and rage, while the central part is involved with aversion, displeasure and a tendency to uncontrollable and loud laughing. However, in general terms, the hypothalamus has more to do with the expression (symptomatic manifestations) of emotions than with the origin of the affective states. When the physical symptoms of emotion appear, the threat they pose returns, via hypothalamus, to the limbic centers and, thence to the pre-frontal nuclei, increasing anxiety. This negative feed-back mechanism can be so strong as to generate a situation of panic.

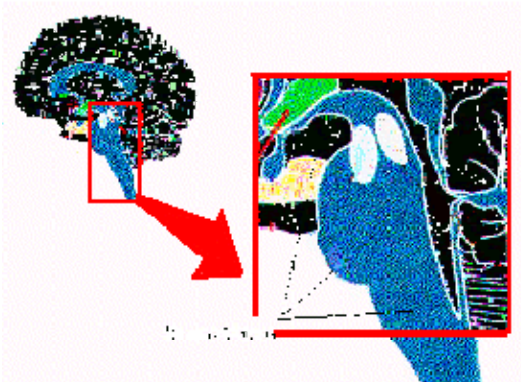
Cingulate Gyrus



It is located in the middle side of the brain. There is still much to be learned about this gyrus, but it is already known that its frontal part coordinates smells and sights with pleasant memories of previous emotions. This region also participates in the emotional reaction to pain and in the regulation of aggressive behavior. Wild animals, submitted to the destruction of the cingulate gyrus (cingulectomy), become totally tamed. The cutting of a single bundle of this gyrus (cingulotomy) reduces pre-existent depression and anxiety levels, by interrupting neural communication across the Papez's circuit.

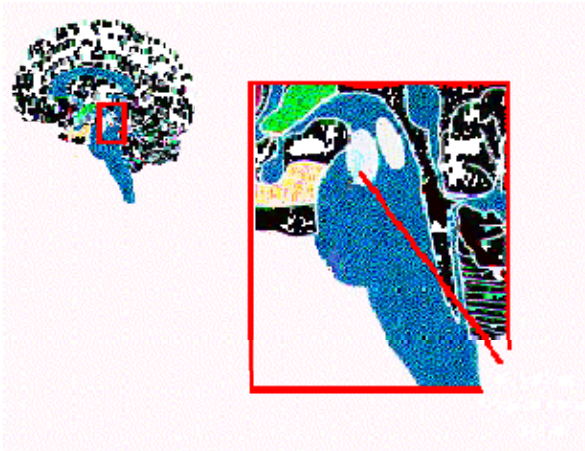


Brainstem



The brainstem is the region responsible for the "emotional reactions", (indeed, they are just reflex answers) of inferior vertebrates, like reptiles and amphibians. The involved structures are the reticular formation, and a concentrated mass of nor-epinephrine secreting neurons. It is important to stress that, even in humans, these primitive structures remain active, not only as alerting mechanisms, vital for survival, but in the maintenance of the sleep-awake cycle.

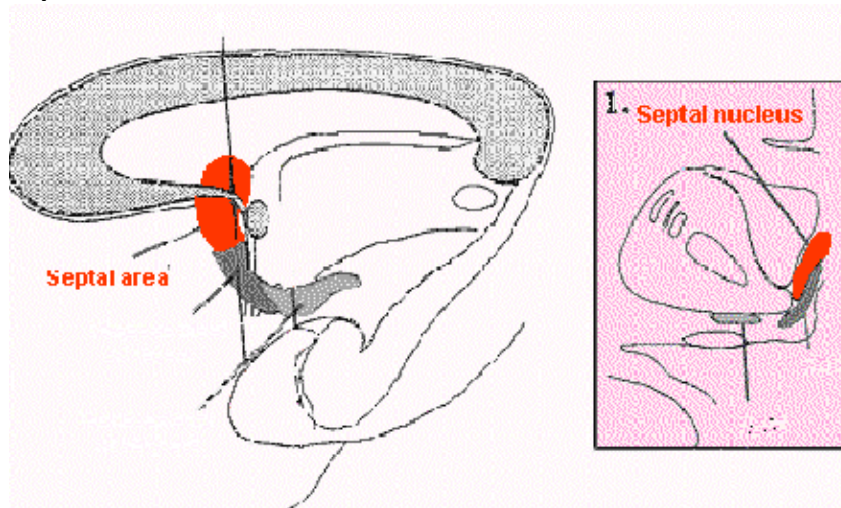
Ventral Tegmental Area



In the ventral tegmental area, located in the middle segment of the brain stem, there is a compact group of dopamine-secreting neurons whose axons end in the region that produces pleasurable sensations, some of them similar to orgasm. Many people who, for a genetic error, have a reduction of D2 (dopamine) receptors in this area, become, sooner or later, incapable of obtaining gratification from the common pleasures of life. Thus, they seek atypical and noxious "pleasurable" alternatives, like alcoholism, cocaine addiction, impulsive gambling and compulsion for sweet foods. Certain brainstem structures, like the nuclei of the cranial nerves, stimulated by impulses coming from the cortex and other structures are responsible for the expressions of anger, joy, sadness, tenderness, etc.



Septum



The septal region lies in front of the thalamus. Inside it, one finds the centers of orgasm (four for women and one for men). This area has been associated with different kinds of pleasant sensations, mainly those related to sexual experiences.

Prefrontal area



This area comprises the entire non-motor region of the frontal brain lobe. It underwent a great deal of development during the evolution of mammals. It is especially large in man and in some species of dolphins. It does not belong to the traditional limbic circuit, but its intense bi-directional connections with thalamus, amygdala and other structures, account for the important role it plays in the origin and, specially, in the expression of emotional states. When the pre-frontal cortex suffers a lesion, the subject loses his sense of social responsibility as well as the capacity for concentration and abstraction. In some cases, although consciousness and some cognitive functions, like speech, remain intact, the subject can no longer solve problems, even the most elementary ones. When pre-frontal lobotomy was used for treatment of certain psychiatric disturbances, the patients entered into a stage of "affective buffer", no longer showing any sign of joy,



sadness, hope or despair. In their words or attitudes, no traces of affection could be detected.



Affective States

Humans display the largest web of connections between the prefrontal area and the traditional limbic structures. Perhaps that is why they present, among all species, the greatest variety of feelings and emotions. Although some signs of affection can be perceived in birds, the limbic system only began to evolve, in fact, after the first mammals, being practically non-existent in reptiles, amphibians and all other preceding species.

The evolution of mammals brings us to mankind. Certainly, our ancestors could already establish differences between the sensations they experienced in distinct occasions, such as being at his cave polishing a stone or a bone, running after a weaker animal, running away from a stronger one, hunting a female of his species, etc.

With the development of language, particular names were given to these sensations, allowing their definition and communication to other members of the group. Since there exists an important subjective component, difficult to be communicated, even today there is no uniformity concerning the best terminology to be used, in order to designate, specifically, many of these sensations.

Therefore, the words **affect**, **emotion** and **feeling** are used interchangeably and imprecisely, almost like synonyms. However, we think that each of these words deserves a precise definition, for the sake of their derivation and because of the physical and mental reactions they cause.

Affect: Affect (from the Latin affectus, meaning to afflict, to shake, to touch) could be defined as "a grouping of physic phenomena apparent under the form of emotions, feelings or passions, always followed by impressions of pleasure or



pain, satisfaction or discontentment, liking or disliking, joy or sorrow". Affect gives a name to events experienced as emotions or feelings.

Emotion: Emotions (from Latin *emovere* meaning moving, or displacing) are apparent reactions to those affective conditions that, due to their intensity, move us to some kind of action. We can say that emotions are characterized by a sudden disruption of the affective balance. Almost always, they are short episodes, with slight or intense, repercussions upon several organs, which can set up partial or total blocking of logical reasoning. This can provoke, in the affected subject, a high degree of psychic and behavioral loss of control. Conversely, feelings are seen as affective states with a longer duration, causing less intensive experiences, with much fewer repercussions upon organic functions and lesser interference on reasoning and behavior.

As an example: Love, fear and hate are feelings (affect). Passion, fright, anger, or wrath is an emotion.

Conclusion

If you got to this point, good for you. I know it was academic and deep but that's what some people ask for. The other articles on the web site make mention of the brain structures mentioned in this article and it can be a good cross reference source. If you have any questions please drop me a line.

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