Emotions

Sang-Hun Lee, PhD
Department of Neurology, UAMS
November 22, 2017
Emotions

- The subjective feelings and associated physiological states
- Expressed through both visceral motor changes and somatic motor responses (e.g., movement of facial muscles)
- The limbic system
- The amygdala: The associative learning via a Hebbian-like mechanism
- The amygdala and fear recognition/expression: A case study
- Emotion (affective) disorders: Major types of psychiatric problems
- The monoamine hypothesis
- The mechanisms underlying antidepressants (e.g., serotonin reuptake blocker)
Facial Expressions of emotions

- The French neurologist and physiologist, G.-B. Duchenne de Boulogne
- The contribution of small groups of cranial muscles to the facial expression
- Transcutaneous electrical stimulation
- The obicularis oculi and the zygomaticus major: Two major muscle groups for real smile
- This natural facial expression: Duchenne smile
- Volitional smile
- What makes the difference between those two types of smiles?
Voluntary and Emotional Facial Paresis

Upper motor neuron syndrome
- damage of descending pathways from the motor cortex
- Unilateral facial paralysis (right side)
- Lower facial muscles

A tumor in the left thalamus
- Disruption of descending pathways from non-classical motor cortical areas
The Caudal Hypothalamus Is Sufficient For The Expression of Emotional Behavior

- Phillip Bard
- The cortex, underlying white matter, and basal ganglia in cats were removed
- The anger behavior occurred spontaneously
  - The typical autonomic components of anger
  - Somatic motor components of anger
  - Sham rage due to no obvious target
- The caudal hypothalamus is a key part for sham rage
- Suggest that cortical processes are not required for the expression of anger
Activation of The Hypothalamus Produced Defensive and Aggressive Behaviors in Cats

The medial hypothalamus - threat attack

The lateral hypothalamus - predatory aggression (silent-biting attack)

**Work**

The diencephalon of both human and animal brains has cells that govern many behaviors. During the 1930s Walter Hess inserted a narrow metal thread into different parts of anesthetized cats' hypothalamus, an area on the underside of the diencephalon. When the cats awoke, he could trigger different behaviors with weak electrical impulses to different parts of the hypothalamus - not just simple reactions but complex behaviors. Among other things, the cats could be made to display defensive and aggressive behaviors and to curl up and go to sleep.

**Walter Hess - Facts**

Walter Rudolf Hess

Born: 17 March 1881, Frauenfeld, Switzerland

Died: 12 August 1973, Ascona, Switzerland

Affiliation at the time of the award: University of Zurich, Zurich, Switzerland

Prize motivation: "for his discovery of the functional organization of the interbrain as a coordinator of the activities of the internal organs"

Field: neurophysiology

Prize share: 1/2
The Reticular Formation: The Major targets of the Hypothalamus

• A tangled web of nerve cells and fibers in the brainstem (> 100 identifiable cell groups)

• Physiological functions:
  • Sleep and wakefulness
  • Cardiovascular function, respiration, urination, vomiting, and swallowing
  • Provide output to somatic and visceral motor effect systems
  • Produce visceral motor and somatic motor responses
The Limbic Lobe

- Paul Broca used the term
- Limbus is Latin for rim
- A rim around the corpus callosum and diencephalon on the medial face of the hemispheres
- Two major components: The cingulate gyrus and the parahippocampal gyrus
- The sense of smell
Papez Circuit

- James Papez speculated that the limbic lobe might be related to emotions
- Mammillary bodies $\rightarrow$ the anterior nucleus of the thalamus $\rightarrow$ the cingulate gyrus
- The cingulate gyrus $\rightarrow$ the hippocampus $\rightarrow$ the fornix $\rightarrow$ the hypothalamus
- Suggested that those circuits are necessary for cortical control of emotional expression
The Limbic System: The system that processes emotions
The Amygdala

- Distinct subgroups
- Medial group: Connections with the olfactory bulb and olfactory cortex
- Basal-lateral group: Connections with the orbital and medial prefrontal cortex and the associational cortex of the anterior temporal lobe → Emotional experience
- Central group: Connections with the hypothalamus and brainstem → Emotional expression
- Highly processed sensory inputs as well as sensory inputs from the thalamus
- Higher order cognition processed in medial prefrontal cortex might be important for cortical control of emotional expression.
Fear and the Human Amygdala: A Case Study

- Urbach-Wiethe disease (autosomal recessive condition): Bilateral calcification and atrophy of the anterior-medial temporal lobes
- The patient (S.M.):
  - Both amygdalas were damaged. However, no obvious damages in the hippocampus and nearby temporal neocortex
  - No obvious deficits in sensory or motor impairment, intelligence, memory, or language function
  - Impaired recognition of the emotion of fear in human face photographs
The S.M. Case Study

- How about in real-life situations?
  - An exotic pet store: No signs of avoidance and an excessive degree of approach to dangerous snakes and spiders
  - A haunted house: No evidence of nervousness and fear
  - Fearful move segments: No fear
  - Self assessment of her everyday emotional experiences over a 3-month period using mobile device: Rate her emotional state according to a set of randomly presented terms: not experiencing fear
- Conclusion: focal bilateral amygdala degeneration → inability to experience fear
The Role of the Amygdala in Evaluating Stimuli in Conditioned Fear Response

- Joseph LeDoux at NYU
- Auditory fear conditioning in rats
- After training, the neural tone evoked an increase in BP and prolonged freezing
- Defined the neural circuits in the amygdala underlying auditory fear conditioning
- Suggested that the amygdala associates diverse sensory inputs, resulting in new behavioral and autonomic responses to auditory stimuli that were previously neutral
Model of Associative Learning in the Amygdala

- Principal neurons in the amygdala
- Receive multiple forms of inputs
- Associations between different forms of inputs
- Long-term potentiation (LTP) in the amygdala: A circuit mechanism underlying learning and memory
- NMDA receptor antagonist blocked the acquisition of conditioned fear as well as LTP
The Associative Learning Process: A Hebbian-Like Mechanism

“Neurons that fire together wire together.”
Mood (Affective) Disorders

- Abnormal regulation of feelings of sadness and happiness
- Major depressive disorder: Persistent and intense feelings of sadness
- Bipolar I disorder (manic depressive disorder): A pattern of cycling between mania and depression
- Depression: 10-25% in women and 5-12% in men
- An abnormal sense of sadness/despair, miserable feelings about the future, disordered eating and weight control, disordered sleeping, poor concentration, diminished pleasure, etc.
- ~50% of all suicides occur in individuals with clinical depression
Depression and Mania: Neurobiological Disorders

- The heritability of these diseases
  - The concordance of affective disorders is high in monozygotic compared with dizygotic twins

- Unipolar depression: Abnormal patterns of blood flow in the "triangular" circuit
  - The amygdala, orbital and medial prefrontal cortex, and mediodorsal nucleus of the thalamus

- Significant correlation of abnormal blood flow in the amygdala and the clinical severity of depression

- Selective serotonin reuptake inhibitors: Most successful antidepressants (e.g., fluoxetine, Prozac®; sertraline, Zoloft®; and paroxetine, Paxil®)
Biological Bases of Mood Disorders: The Monoamine Hypothesis

• Reserpine → severe depression: Reserpine → depletion of catecholamine and serotonin
• Monoamine oxidase (MAO) inhibitors → mood elevation
• The hypothesis that mood is closely tied to the levels of released “monoamine” neurotransmitter (e.g., norepinephrine and/or serotonin) in the brain: A deficit in one of these diffuse modulatory system
Antidepressant Drugs and the Underlying Mechanisms

Selective serotonin reuptake inhibitors:
Most successful antidepressants (e.g., fluorepine, Prozac®; sertraline, Zoloft®; and paroxetine, Paxil®)

MAO inhibitors:
phenelzine
Lithium: A Highly Effective Chemical Element for Treatments of Bipolar Disorders

• The mood-stabilizing effect of lithium treatment in five patients

- Lithium interferes with intracellular signaling that is associated with PIP2 (phosphatidyl inositol) and adenylyl cyclase
Summary

- Two parallel pathways for facial expression: Volitional movement and emotional expression pathways
- The limbic system: The emotion system
- The amygdala: The structure, the S.M case study, the associative learning process (Hebbian mechanism in the amygdala)
- Mood disorders and the monoamine hypothesis
- The underlying mechanisms of antidepressants and lithium for treatments of mood disorders
Happy Thanksgiving