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Understanding emotions

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SOMMAIRE

1. INTRODUCTION

Could you ever imagine life without emotions? To eat your favorite dish without any joy? To ignore fear? To live with your beloved without love or to love without laughs or cries? Wouldn't we all behave like robots? The entire humanity would have lost its soul…

In fact, emotions are totally part of our life and shape every one of us differently. They color our life experiences and give them meaning and flavor. Despite their fundamental presence in our lives, emotional functioning remains unclear although they have been the center of interest of researchers for over a century.

The personal work introduces the concept of emotions, how they seem to function and their classification. As second step, we enumerate some classical theories which have described how emotions are generated and propagated into our bodies. Lastly, some contemporary theories based on a refinement of the classical ones are presented.

2. WHAT IS AN EMOTION ?

An emotion is an intense and complex psychophysiological experience, that occurs by neurophysiological changes, variously associated with thoughts, feelings, behavioral responses, and a degree of pleasure or displeasure. Emotions are the responses to significant internal and external events. They can come up in any form such as occurrences, dispositions, short-lived.

Emotions have played a fundamental role in survival during human evolution and in effective psychological functioning in human societies. In contrast to reflexes, which are automatic and uncontrollable narrowly tuned responses to specific stimuli, emotions actually developed and were selected in evolution as adaptive mechanisms to help humans navigate an ever-changing environment. These modifications were crucial for the ability to find food, care for offspring, and also to avoid danger and escape from life-threatening situations. It has been speculated that emotions first emerged when reflexive responses became more complex, introducing additional neural layers that led to the development of central emotional states.

Most modern theories of emotion are stem from the idea that emotions are biologically determined. The primary emotions such as fear, joy sadness, disgust and surprise are the evidence to this approach, because they are innate and appear within the first six months of life and are linked to specific facial expressions. Research has proven that emotions have been equally recognized in different cultures across the world. According to Ekman and colleagues, people from different backgrounds do not just interpret but they also reproduce facial expressions of primary emotions in similar ways. Despite the ability to recognize these expressions is still consistent across cultures, the perceived intensity of emotions can vary depending on cultural context.

Charles Darwin was probably the first one to analyze and study the evolution of emotional reactions and facial expressions, highlighting their significance in an organism's adaptation to environmental stimuli. In his book, *The Expression of the Emotions in Man and Animals*, he made some detailed descriptions of an individual's facial expressions as well as the motor mechanisms involved in expressing each emotion. He then proposed that both humans and animals share a common evolutionary history.

His work demonstrated that certain emotional facial expressions have universal meaning for people in different parts of the world. Darwin foresaw research of facial expressions would not start until more than a century later. From an evolutionary perspective, emotions serve to coordinate various physiological and behavioral processes, helping individuals respond effectively to immediate challenges.

3. THE FUNCTIONING OF EMOTIONS

The limbic system is the brain region that governs the emotions. It is crucial for behaviors we need for survival: feeding, reproduction and caring for our young, and fight or flight responses. The limbic system is a complex network of structures, including the amygdala, hippocampus, and hypothalamus. The hypothalamus converts emotion into a physical response, so he activates the sympathetic nervous system. The thalamus is basically a sensory relay station, with neurons that extend to the amygdala and higher cortical areas for advanced processing. The hippocampus is the part of the brain that combines emotional experiences with cognitive functions. The amygdala is crucial in the processing of emotional information before giving it onward.

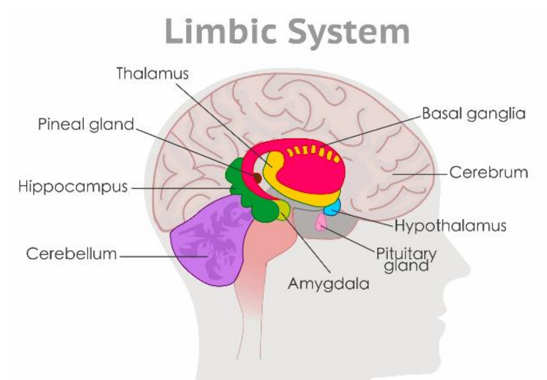


Figure 1 Limbic system

- **Amygdala**

  Amygdala or also called almond nucleus, because of its complex of nuclei, which is a cluster of neurons in the center of the nervous system, is a really small almond shaped part of our brain. It is the main processing center for emotions. The amygdala plays an essential role in survival, so it automatically detects danger and alerts us before even our conscious mind has time to react to it.

  According to J. LeDoux, an American neuroscientist whose research is primarily focused on survival circuits including their impacts on emotions, the amygdala plays a crucial role in processing emotions but especially the emotions that are related to anxiety and fear. The function of the amygdala does not end with sensing danger and feeling fear but in contrary it is involved in a spectrum of emotions which goes from joy to anger or sorrow. So, this small brain area is linked to our attention and sensitivity toward emotionally charged events.

  The amygdala is composed of various subnuclei. A subnucleus is a subdivision of a nucleus especially of nervous tissue. These include the basolateral complex and the central nucleus. The basolateral complex maintains numerous connections with various sensory areas of the brain. It is essential for classical conditioning and for assigning emotional value to learning and memory. The central nucleus is involved in attention and connects with the hypothalamus and several brainstem regions to regulate the activity of the autonomic nervous and endocrine systems.

Every experience in our life can shape the amygdala’s function, especially in infancy. The kids that experience lack of care and chronic stress are likely to suffer from changes in how their amygdala responds to emotional situations. It can even come from the parents, so when a mother goes through depression while being pregnant, it can influence the amygdala's connectivity in the child emphasizing the profound impact of early environments on our emotional processing.

- **Hippocampus**

  The name of the hippocampus comes from its shape that looks like a curvy seahorse. It is fundamentally the memory center of our brain where our episodic memories, the memories that have happened to us, are formed and classified and then filed away in long term storage which is across other parts of the cerebral cortex.

  The links in the hippocampus help us associate a specific memory with a sense, for example, associating the smell of sunscreen with summer. The hippocampus is one site in the brain that even throughout adulthood generates new neurons. This process is called neurogenesis and is the basis of one type of brain plasticity, which is the ability of the brain to change, adapt and reorganize itself in response to new experiences, learning, or injury throughout life.

4. CLASSIFICATION OF EMOTIONS

Paul Ekman is a psychologist and a pioneer in the study of emotions and facial expressions. He also proposed that certain emotions are universal across all human cultures and are linked to facial expressions distinct facial expressions. He created his theory on the base of Charles Darwin’s work, that argued that emotions have evolutionary significance and are biologically rooted. He identified six basic emotions that are universally recognized: Happiness, Sadness, Anger, Fear, Surprise and Disgust.

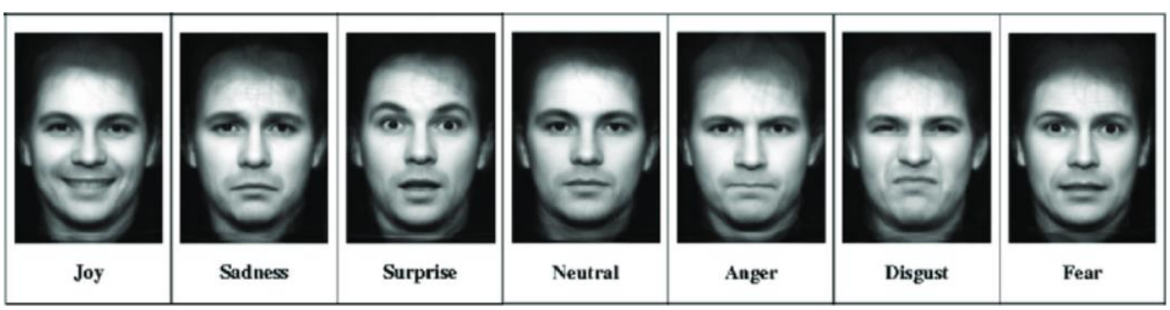


Figure 2 Six basic emotions as described by Ekman

These emotions are facially expressed in every part of the world regardless of culture, language, or upbringing. Ekman also made a popular study to test these universal facial expressions. In this study he studied Fore people, which are people that are an isolated tribe in Papua New Guinea. He chose the Fore people because they do not have anything to do with the rest of the world. So, he showed them pictures of facial expressions and asked them to match them with stories, for example “who is scared”. Their answers matched perfectly with the people from industrialized societies, which proved that face expressions are universal.

So according to Ekman emotions are innate with us and not just learned, we all also share a common “emotional language” in our facial expressions. Ekman's research changed how us humans understand emotions, and even helped in fields like lie detection and emotional AI.

5. CLASSICAL THEORIES OF EMOTIONS

The study of emotions has intrigued philosophers and scientists for centuries, going until Ancient Greece. But it was only in the 19th and 20th centuries that more structured psychological theories began to emerge. Over time, researchers have developed a variety of approaches to explain what emotions are, how they arise, and how they affect human behavior. This section presents some of the most significant theories of emotion.

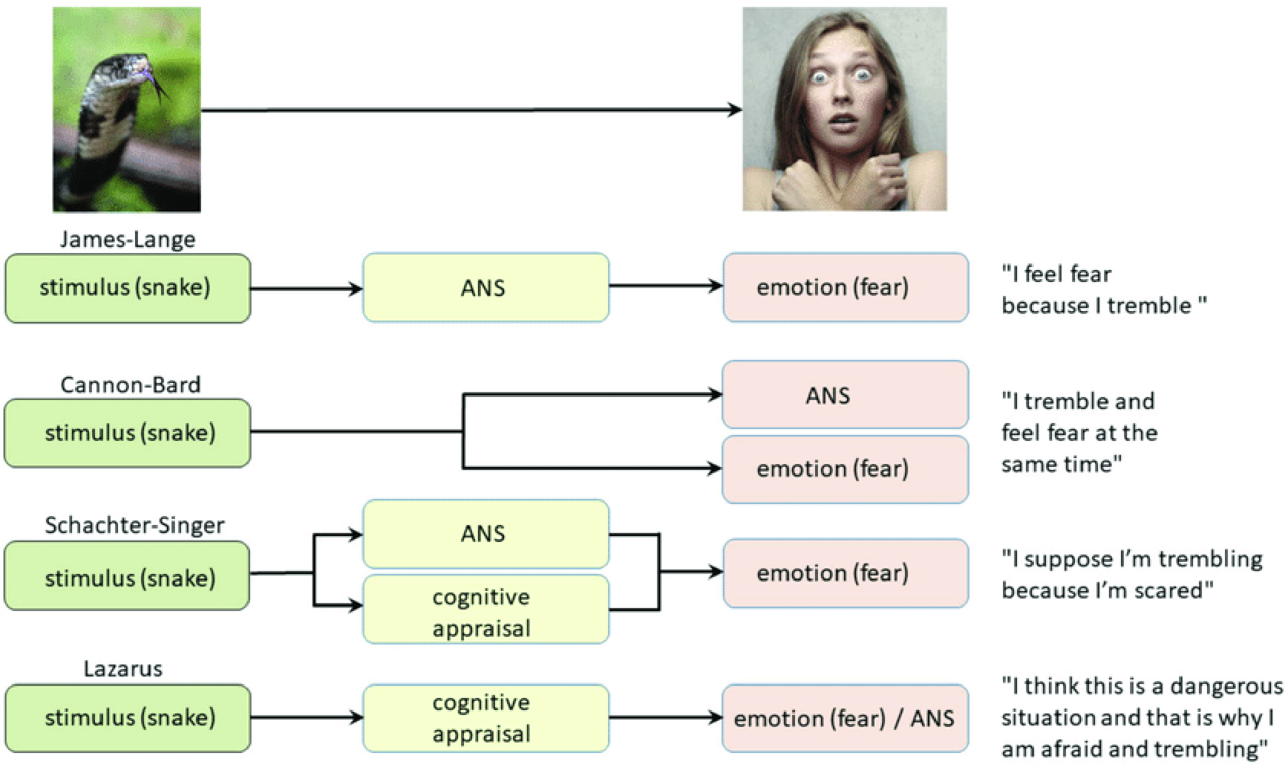


Figure 3 Illustration of the classical theories of emotions

5.1. Theory of James-Lange

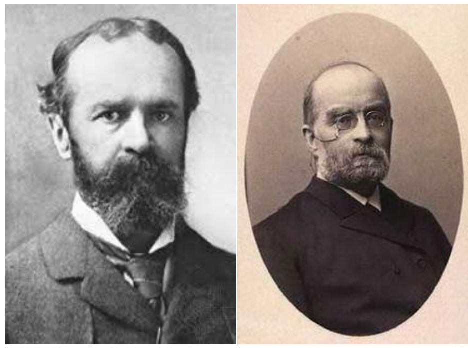


Figure 4 William James (left) and Carl Lange (right)

The James-Lange theory of emotion is one of the earliest attempts to explain what causes emotions. It was proposed by psychologist William James and physiologist Carl Lange in the mid 1880s

The James-Lange theory of emotion is based on the idea that physical changes in the body happen before the experience of the associated emotion. So, according to his theory, emotions stem from our interpretation of our physical sensations. For example, you are swimming in the ocean, and you see a shark fin. Your body starts to tremble, and your heartbeat is racing. The James-Lange theory states that you will interpret your physical reactions and conclude that you are frightened.

Their theory states that our emotions are caused by our interpretation of our bodily reactions. Our physiological bodily reaction occurs first and then is followed by an emotional reaction "we are afraid because we run". In other words, this theory states that first there must be a physiological response to an environmental stimuli and then the way a person interpretates that physical response will lead them to an emotional response.

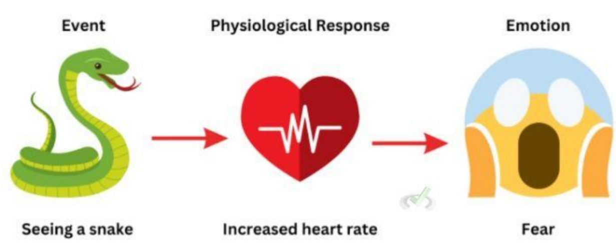


Figure 5 Emotion processus as described by James-Lange theory

First some specific areas of the brain such as the visual or auditory cortices process a particular stimulus and evaluate its meaning and relevance. If the stimulus is emotionally important, the information is relayed to the Autonomic Nervous System (ANS). The ANS is a network of nerves, component of the peripheral nervous system, that regulates involuntary physiologic processes including heart rate, blood pressure, respiration, digestion, etc. Then the "conscious part" of the brain detects the bodily arousal and interprets the emotional nature of the experienced physiological state.

James and Lange both believed that it was impossible just to imagine experiencing an emotion, such as anger or fear. It would always just be a flat and fade replica of the real feeling. Because they think that without the physiological response it would be impossible to experience these emotions on demand. So there has to be a physical reaction in order to actually experience real emotion.

William James explained, "*My thesis, on the contrary, is that the bodily changes follow directly the PERCEPTION of the exciting fact and that our feeling of the same changes as they occur IS the emotion.*". According to what he says, different emotions are experienced differently because they arise from different constellations of physiological responses.

This James–Lange theory has been later called the peripheral theory of emotions because it emphasizes the importance of bodily responses for the emergence of emotions.

One example in favor of the James-Lange theory of emotion is the effect of benzodiazepines, a class of anxiolytic drugs, which are also muscle relaxants. According to the theory, tense muscles signal anxiety to the brain. So, when muscles relax, the brain no longer receives this information, and the subject becomes less anxious.

James-Lange Theory Criticisms

James and Lange did present some clinical findings to support their theory. For instance, Lange once cited a physician's observation that when a patient is angry then their blood flow to the skull increased, which he interpreted as supporting his idea that a physical response to a stimuli led to the experience of that emotion.

The main criticism of their theory was that their concepts and findings were not based on any controlled experiments. Rather, the theory was largely the result of introspection and correlational research.

Neuroscientists kept finding flaws in James and Langes theory such as a work made by a neuroscientist and experimental physiologist who revealed that both animals and humans who had lost major sensory capabilities were still able of experiencing emotions. So they discovered that people with muscle paralysis and lack of sensation were still able to feel emotions such as joy, fear and anger.

Another experiment pointed out another flaw of that theory. The experiment consisted in applying electrical stimulation onto a specific body part a few times and see if the same emotion would get triggered, but that wasn't the case. The conclusion of that experience concluded that a person may have the exact same physiological response to a stimulus but still won't experience the same emotion. This proved that there are way more factors that should be considered such as the individual's existing mental state, cues in the environment and the reaction of other people, which can also play a big role in the resulting emotional response.

Support for the James-Lange Theory

The James-Lange theory is not just studied because of its historical significance, but also because it maintains its relevance now. Still today researchers discover evidence that supports at least parts of James's and Lange's original ideas. Thanks to new technology researchers were allowed to get a better understanding of how the brain and body respond during an emotional reaction.

For example, a classic study which was published in 1990 showed that James and Lange were not completely wrong. They found that when people were asked to make facial expressions for different emotions, they revealed slight differences in their psychological reactions.

Another study states that the way a person perceives their internal physical states acts a part in how they experience emotions. So that study found that participants who were more sensitive to their body's physical signals also experienced more negative emotions such as anxiety.

5.2. The Cannon-Bard Thalamic Theory of emotion

The Cannon-Bard theory of emotion was proposed in the 1920s by Walter Cannon and Philip Bard. It directly challenged the James-Lange theory. Cannon and Bard's theory suggested that our physiological reactions, such as crying and trembling, are caused by our emotions.

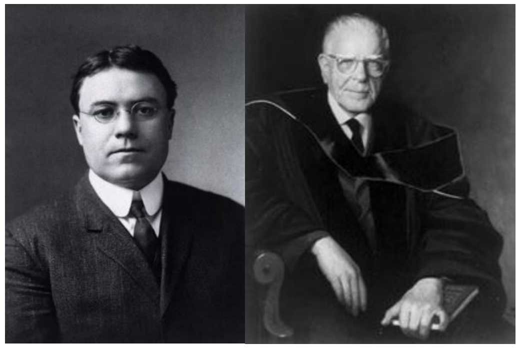


Figure 6 Walter Cannon (left) and Philip Bard (right)

According to the Cannon-Bard theory of emotion, we react to a stimulus and experience the associated emotion simultaneously, because the brain processes both these aspects at the same time through the thalamus. The thalamus is a small oval-shaped structure within the brain who's primary function is to relay motor and sensory signals to the cerebral cortex, so it plays an important role in emotional processing. It also sends signals to the autonomic nervous system, following up in physical reactions such as muscle tension, shaking and sweating. Since the thalamic region plays such a big role in this theory, it is also referred to as the *Thalamic Theory of Emotion*.

In comparison to the James-Lange theory, Cannon and Bard suggested that the physical reactions and emotional responses do not cause each other. The theory basically says that the brain processes both emotions and the bodily reaction simultaneously as the response to the external stimulus. Both reactions are part of two distinct pathways. One path is the thalamus which sent signals to the brain's emotional center, the limbic system, which produced the conscious emotional experience. The other path goes through the ANS which triggers the bodily responses.

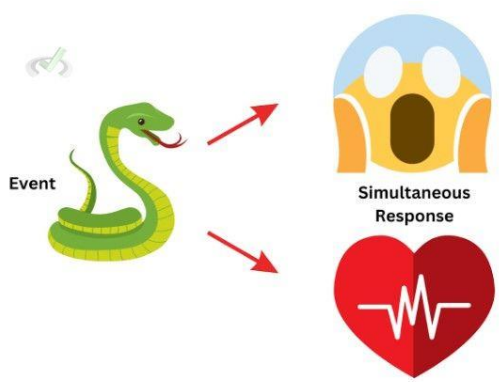


Figure 7 Emotion processus as described by the Cannon-Bard theory

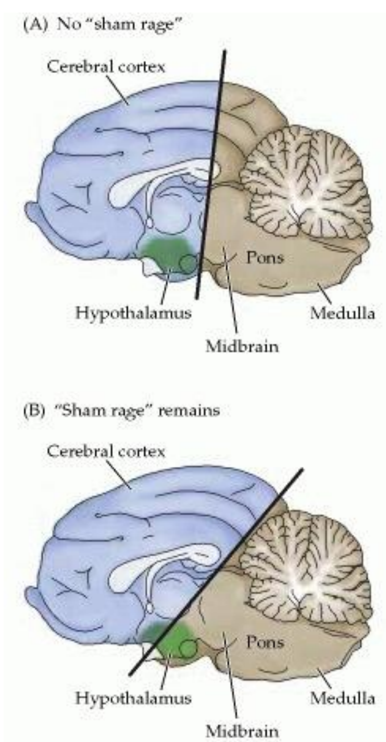
For example, when a scary situation is perceived, the brain and more specifically the thalamus processes the emotion in this case fear. Your body responds at the same time, increasing your heart rate and making you sweat. Both the emotional experience and the physiological experience happen at the same time but are not connected, they are independent from each other.

The Sham Rage Experiment

In this experiment Phillip Bard conducted a succession of surgical procedures in cats, with the aim of exploring the neural basis of emotions, in this case particularly anger. First, Bard removed some parts of the brain, more specifically both hemispheres, which are involved in higher-order functions like cognition and voluntary movement. The hemispheres include the cortex, which is responsible for any conscious thoughts and perceptions, and also the basal ganglia which is fundamental for motor control.

After the anesthesia wore off, the cats expressed signs of anger, even though there was no external stimuli nor threat. Bard called this behavior "*sham rage*", because it looked just like a natural emotional response, but also did not have any specific cause or target. These behaviors included increased blood pressure and heart rate, pupil dilation, erection of the hairs, arch-back, claw extension and tail lashing. This behavior is actually typical autonomic and somatic responses linked to intense emotional states like anger.

With this experiment Bard finally demonstrated that the full *sham rage* response could still occur as long as the back part of the hypothalamus, caudal hypothalamus, was intact. The thalamus, a crucial part of the brain, regulates autonomic functions and plays a key role in emotional processing and behavioral responses, including the fight-or-flight reaction. Bard also took it a bit further by cutting at the junction of the hypothalamus and midbrain. This cut stopped the sham rage behaviors although some uncoordinated components of the behavior were still visible. This proved that coordinated emotional behavior like aggressive actions associated with anger requires an intact connection between the hypothalamus and midbrain.



(A) Transection through the midbrain

Cutting the brain at the junction of the hypothalamus and midbrain stops the coordinated sham rage response. Even though the brain and the body are disconnected, the expression of emotional behavior like in this case sham rage can no longer occur.

(B) Hypothalamus Intact

When the hypothalamus is still intact, all the components of the emotional response remain active. The autonomic changes like heart rate and the behavior like aggression, can still occur, even if the higher brain regions are removed.

Cannon-Bard Theory Criticisms

Critics demonstrate that the Cannon-Bard theory pays too much attention to the role that the thalamus really has and completely ignores the other parts of the brain. The Thalamus does play a huge role in the process of feeling and emotion, but some recent research argues that this process is more complex than what the Cannon-Bard theory implies.

For example, according to the Cannon-Bard theory, physical reactions do not lead to emotions but there have been multiple studies that have proven this wrong such as a recent study that showed that when people were asked to make a particular facial expression, they were most likely to also experience an emotion connected to that expression.

5.3. The Schachter-Singer Two -Factor Theory of emotion

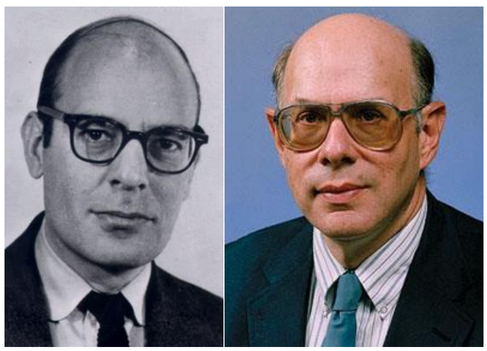


Figure 8 Stanley Schachter (left) and Jerome Singer (right)

During the late 1960s, a lot of cognitive theories of emotion emerged. This period has been called the "cognition revolution" in psychology. One of the first theories at that time was the one suggested by Stanley Schachter and Jerome Singer which is called the *Two-Factor Theory of Emotion*.

According to the Schachter-Singer theory of emotion there are only two key factors of emotion. The first one is physical arousal, and the second one is cognitive label. This theory really focuses on the interaction between those two factors. When, you experience something that triggers an emotional response your body will first have some kind of physiological response which the brain then identifies, because simply feeling arousal is not enough, we must identify the arousal in order to feel the emotion. This theory considers that different contexts can lead to other emotions from the same physiological state.

For example, if you see a snake, your body might respond with an increased heart rate. You then think about why your heart is racing, realize it's because of the snake, and conclude that you are afraid. This theory emphasizes that our thoughts help determine our emotions.

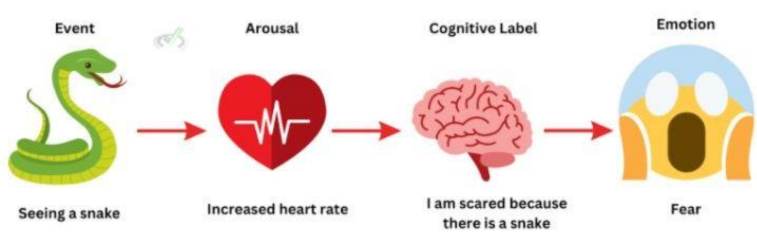


Figure 9 Emotion processus as described by the Schachter-Singer theory

Schachter and Singer's Experiment

To prove their theory, they decided to conduct an experiment. In 1962, they gathered a group of 184 male participants from the university of Minnesota, and told them they were participants in a study on the effects of vitamin supplement on visual abilities.

Some of the participants were injected with either *epinephrine*, an adrenaline solution that engenders arousal such as increased heartbeat, trembling and rapid breathing, or with a placebo which is completely neutral and did not have any physiological effects. Some participants having received the *epinephrine* were correctly informed that they had an injection of adrenaline and were called the *Informed group.* A second group of participants was told false side effects, for example itching or headache, to mislead them. A third group of was told nothing about potential side effects, the *Ignorant group*. And the last group, the *Placebo group*, was represented by those who did receive the placebo.

After the injection, the participants were placed in one of two emotional contexts, euphoric condition and into an angry condition. In the euphoric condition was a assistant, an actor who was working with the researchers, who acted playfully engaging in fun activities like throwing paper planes with the aim of creating a happy atmosphere. The other condition was the angry condition where there was an assistant who acted irritated, complaining about the experiment and constantly expressing anger.

The results of this study actually ended up supported the two-factor theory of emotion because the participants from the *Ignorant group* were more likely to adopt the emotional tone of the emotional context. So in the euphoric condition they felt happy and the angry one they felt angry. They felt that way because since they had no explanation for their physiological arousal, they looked to the social context to interpret their feelings.

The participants of the *Informed group* were less likely to be influenced by the emotional context as they already had attributed their arousal to the injection's side effects, they did not have to rely on external emotional cues. The participants from the *Misinformed group* also adopted the emotional tone of the confederate because they were given false informations and had to rely on external cues to interpret their feelings. The participants of the *Placebo group* revealed lower levels of emotional response overall, because without the arousal they were less likely to experience strong emotions, even in emotional contexts.

Schachter and Singer concluded that emotion really results from the interaction between physiological arousal and cognitive labeling.

Two-Factors Theory Criticisms

Sadly other researchers have only partially supported the findings of the original study and have at times shown contradictory results. Marshall and Zimbardo who are two researchers who conducted that experiment again found that participants were no more likely to act euphoric when exposed to a euphoric confederate than when they were exposed to a neutral confederate. In another study by Maslach, hypnotic suggestion was used to induce arousal rather than injecting epinephrine. The results suggested that unexplained physical arousal was more likely to generate negative emotions no matter which type of confederate condition they were exposed to.

Other criticisms of the two-factor theory include, sometimes emotions are experienced before we think about them. Other researchers have supported James-Lange's initial suggestion that there are actual physiological differences between emotions.

5.4. THEORY OF LAZARUS

Figure 10 Richard S. Lazarus

The Lazarus theory of Emotion which is also known as the *Cognitive Appraisal Theory*, was introduced in 1966 by the psychologist Richard S. Lazarus. This theory emphasizes the central role of cognition in the emotional process. Richars Lazarus argued that emotions are not autonomic responses to stimuli but on the contrary our interpretations of that stimuli. This theory is a two-steps cognitive process which involves the appraisal of a situation and the subsequent interpretation of its personal relevance.

The first step in the Lazarus theory of emotion is cognitive appraisal, which determines whether the situation is perceived as positive, negative or neutral and how we should respond emotionally. Without this step Lazarus stated that an emotion could not occur because according to him they arise only after we cognitively appraise a situation.

This appraisal process can be broken down into two components:

- The primary appraisal is basically the initial evaluation of a situation or event which focuses on the events relevance to the individual's well-being, goals or values. The individual then has to assess whether the event is irrelevant, being-positive, or stressful, so it could for example be threatening, challenging or harmful.
- The secondary appraisal involves evaluating the individual's resources such as coping abilities and potential responses to deal with the event. It really helps determine the intensity of the emotional response and the type of coping strategies employed.

The result of this cognitive appraisal process is the emotional response. So, the emotion is shaped by the individual's perception of the situation and their evaluation of their ability to cope with it directly. In other words, emotions are not solely determined by the situation, but rather, they depend on how the individual interprets and evaluates the situation's personal relevance and their coping capacity.

Coping strategies are critical for managing emotional responses generated by the cognitive appraisal process and represent the second step in the Lazarus theory of emotion.

Lazarus identified two main coping types:

- The first one is problem-focused coping, which deals with the cause of stress directly, so for example preparing for an exam.
- The second one is the emotional-focused coping, and it manages emotional response itself. For example, seeking social support or using relaxation techniques.

The Lazarus Theory of Emotion really emphasizes that emotions are not static. Instead, the emotional experience is a dynamic and ongoing process. Emotions change as our appraisals of situations evolve. For example, a threatening situation might seem less stressful after receiving support or developing a plan. Thus, because individuals continually appraise and reappraise situations, their emotional responses and coping strategies might change accordingly.

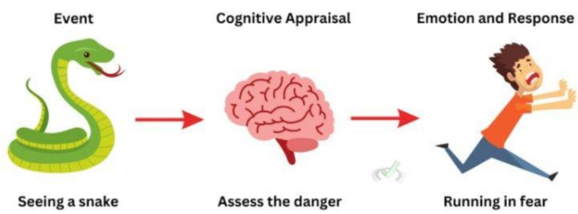


Figure 11 Emotion processus as described by the Lazarus theory

The Lazarus Theory of Emotion revolutionized and reshaped the understanding of emotion by positioning cognition as a key determinant of emotional experience. Lazarus highlighted how individuals assess and respond to events very differently, depending on each individuals' goal, resources and interpretations.

This theory does not only help us understand how emotions work but even help us to cope with them, such as managing stress. Lazarus's influence extends beyond academic psychology into real-world applications such as therapy, stress management, and interpersonal relationships ensuring its lasting relevance.

Lazarus Theory Criticisms
Critics argue that emotions can occur without conscious cognitive appraisal. For example, some emotional reactions can be immediate and automatic as suggested by Joseph LeDoux's work on neural pathways. Also some critics say that the theory is too complex because of the two-stage appraisal process which can seem overly detailed and hard to test empirically. The Lazarus theory was also focusing on the cognitive processes which leads some to argue that his theory underrepresents the biological basis of emotion.

6. Contemporary theories of emotions

Recently, there have been many attempts to provide a single, all-inclusive, universal theory of emotions. The most acknowledged ones are the *Somatic Marker Hypothesis*, the *Higher-Order Theory of Emotional Consciousness* and the *Constructed Theory of Emotions.*

6.1. Somatic marker hypothesis- interoceptive theory of emotion

The *Somatic Marker Hypothesis* is a theory in neuroscience and psychology which was developed by the neuroscientist Antonio Damasio in the 1990s. The theory proposes that emotional processes guide our behavior, particularly decision-making, especially when we are faced with complex or uncertain choices.

Figure 12 Antonio Damasio

According to the theory, the brain uses bodily responses to guide decision-making in subtle ways, often without us consciously realizing it. These responses act as some kind of "emotional shorthand" and signals whether an option is likely to lead to positive or negative outcomes based on prior experiences.

One of the key ideas of the theory are the somatic markers, which can be broken down into the "somatic" and the "markers". "Somatic" refers to bodily sensations, especially those who are linked with emotions, for example feeling a rush of warmth when you feel loved. "Markers" are emotional reactions that are attached to specific events or outcomes based on past experiences. These markers are like "tags" on certain choices or situations that carry emotional significance. The somatic markers are probably stored in the ventromedial prefrontal cortex.

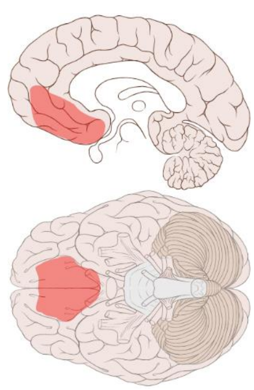


Figure 13 Ventromedial prefrontal cortex

According to Damasio, emotions are not just there to disorient our judgment or distract us, but they actually are to serve a critical purpose in helping us make better decisions. For example, when we are faced with a decision, our brain accesses the somatic markers, which are emotional memories linked to similar past situations. These feelings act as some kind of "shortcut" for our decision-making, and that guides us towards or away from a certain action.

These processes involve both the brain and the body. So, the brain first interprets the environment and the past experiences and then, generates an emotional response that will be felt in the body. The prefrontal cortex and the ventromedial prefrontal cortex are really important in this process. The somatic markers aren't just random, they are actually based on already lived experiences. So, for example, if you've faced a decision before which led to a positive outcome, your body might give you a subtle signal, such as a warm feeling or a sense of calm.

Damasio's Experiments

- The Iowa Gambling Task (IGT)

  The Iowa Gambling Task was developed by Antonio Damasio and some of his colleagues in 1994 to study the relationship between emotions and decision-making. The task consists of four decks of card from which the participants have to choose from, each deck of cards associated with different reward and penalty structures. There were 2 "good" decks of cards, which provided smaller rewards but the penalties are low. The other 2 decks were the so called "bad" cards which offered larger rewards, but the penalties were much larger, leading to net loss over time.

  There were two groups of participants. The first group was made of *Healthy individuals* and the second one was composed of patients with ventromedial prefrontal cortex (vmPFC) damage. The participants were not at all informed about the "good" or "bad" decks of cards and had to learn through trials and errors. This task was designed to create this feeling of uncertainty, where the participants have to rely on their past experiences with the decks to make better decisions

  The results of this experiment was that the *Healthy individuals* slowly shifted their preference for the "good" decks avoiding the "bad" decks, after experiencing losses. This decision shift was accompanied by changes in their physiological responses as they were prepared to make a risky decision. These physiological changes were detected before the participant consciously realized they were about to make a poor decision. On the other hand, the patients with ventromedial prefrontal cortex (vmPFC) damage did really bad at this task. They kept choosing from the "bad" decks even when they could articulate the best strategy logically. They never showed any of the usual physiological responses that would signal a "bad" choice. So despite understanding the task logically, they still could not avoid the risky decks. In this case we can really see how important somatic markers are. Healthy individuals' physiological responses act as somatic markers, guiding them away from risky choices. But on the other hand, patients with vmPFC damage lacked these markers, which made them choose the "bad" cards.

  In conclusion, the IGT is a clear evidence for the somatic markers in decision-making. These markers, such as emotional responses that manifest physiologically, provide early cues about the risks involved in certain decisions, even before conscious reasoning takes place. When these emotional cues are missing ,as in patients with vmPFC damage, decision-making becomes impaired.

- Skin Conductance Response (SCR) Study

  The *Skin Conductance Response* study was conducted by Antonio Damasio and some other neuroscientists and psychologists in 1996. The goal was to investigate whether *Skin Conductance Response (SCR)* are able to predict risky decision-making and whether vmPFC-damaged patients lack bodily warning signals.

  They conducted the IGT experiment and during the process they measured the participants skin sweating which is a physiological marker of stress or arousal, with electrodes that were attached to participants' fingertips. During the task they took two measurements, the Anticipatory SCR and the Outcome SCR. The anticipatory SCR was measured before making a choice, to see if the body reacts before picking a risky deck, and the outcome SCR was measured after seeing the result so whether the body reacts when loosing money or not.

  The healthy participants actually showed strong anticipatory SCR before picking a risky deck, so their bodies was trying to warn them before a bad decision. Over time they also listened to their bodies and avoided risky decks, they used emotional signals to guide them towards the right choices.

  However, the vmPFC-Damaged Patients had a lot more difficulties. They did not have any anticipatory SCR before risky choices, so they had no bodily warning signals before making bad decisions. Regardless of their previous mistakes they still had an emotional response after losing the money, so their brain actually was able to recognize a bad outcome, but only after it already happened, so it was too late to prevent it.

  The *SCR* study was groundbreaking because it proved that emotions are not obstacles to rational thought but are essential for good decision-making. It provided strong neurological evidence for the Somatic Marker Hypothesis and changed how we understand the relationship between emotion, reasoning, and behavior.

- Gambling and Emotional Impairment Study

  This study was built upon earlier research, particularly the *Iowa Gambling Task (IGT)* and *Skin Conductance Response (SCR)* studies, to further explore how different types of brain damage affect decision-making and emotional responses. It was published in 1999 and conducted by Antoine Bechara, Antonio Damasio, Hanna Damasio, and Steven W. Anderson. The goal was to simply investigate how different brain lesions affect decision-making, particularly in risky situations.

  In this study they had 3 groups:
    - Healthy Control Group, patients who had no brain damage
    - vmPFC-Damaged Group, patients with lesions in the ventromedial prefrontal cortex,
    - Amygdala-Damaged Group Patients with damage to the amygdala.

  The procedure was similar to the Iowa gambling task but was putting more emphasis on emotional responses after bad decisions. They found that the vmPFC patients acted as usual, so they kept making bad choices and actually had a normal emotional response after that but couldn't use it to guide them towards the right choices. The Amygdala-Damaged patients did not react emotionally after losing money and they didn't show any signs of regret or fear of losing money.

In conclusion, this proves how the vmPFC is necessary for learning from past emotional experiences and the amygdala crucial for generating emotional responses. These two regions both work together to help people make smart choices.

- Emotional and Memory Link Study

  This goal of this study was to see whether emotions influence memory and decision-making. There were two groups of participants, the ones with a healthy brain and patients with damage to the ventromedial prefrontal cortex. These two groups were confronted with emotional pictures of, for example a car crash or a crying baby and also with neutral pictures of a pillow or a lamp.

  During the experiment their brain activity and memory retention were measured. They found out that the healthy participants remembered the emotional images better than the neutral ones. The vmPFC patients had more difficulties remembering the emotional images, so they had weaker memories of emotional events.

  That proves that the vmPFC links emotions to memory which helps individuals to remember important past events and make better future decisions. Without that emotional input, decision-making becomes random and impulsive.

Application of Damasio's Theory

Since the day Damasio first put out the *Somatic Marker Hypothesis*, numerous fields have explored the hidden facets of emotions in decision-making. For example, in economics, health, aging, politics and the study of individual differences in decision-making. His theory is repeatedly used to explain risky behaviors such as unsafe sex, gambling and drug use. SMH proposes that drug-addicted persons may be more likely to use drugs because they aren't able to use emotional signals to compare short-term gains and long-term losses. This research allows us to better understand why some may make some questionable choices and repeatedly put themselves at risk, as it explains that some populations may lack an unconscious advantage.

Somatic Markers Hypothesis Theory Criticisms

Although many researchers agree the SMH explains how emotions guide decision-making, some still have a critical point of view on it. For instance, there are some methodological issues in the Iowa Gambling Task that maybe undermine the proof that unconscious bodily signals influence decision-making. Some studies suggest that participants rely on explicit reasoning instead. There is also an unclear role of bodily responses, because the psychophysiological data are a bit vague, it is pretty unclear whether bodily signals cause decision-making biases or just correlate with them. Decision-making also depends more on cognitive strategies and actually implicit learning rather than emotions or somatic markers.

6.2. HIGHER-ORDER THEORY OF EMOTIONAL CONSCIOUSNESS

The *Higher-order theory of emotional consciousness* is a theory which was developed by the neuroscientist J. LeDoux in 2017. In his theory, LeDoux challenges the conventional view where emotions are programmed in subcortical circuits, and propose instead that emotions are higher order states instantiated in cortical circuits, the higher-order of consciousness.

6.2.1. Higher-order theory of consciousness

The *Higher-Order Theory* of Consciousness, called HOT, tries to explain the difference between unconscious and conscious mental states. So, it states that we are only conscious of a mental state if we have a higher-order representation of it. It basically means that we must have a thought about the mental state for it to be consciously experienced. So, for example, if you see a red cherry but do not reflect on it then you must have a first-order perception, which means that your brain processes a visual input. If you then think "there is a red cherry", then you have a Higher-Order thought HOT about the perception, which makes it a conscious experiment.

There are two states in this process, in which the first one is the first-order states which are basic sensory perceptions, just like seeing hearing or even feeling pain, and the second one are the Higher-Order states which are thoughts about our perceptions, for example "I know I am seeing a red cherry". So, consciousness requires higher-order awareness, and if you do not form a HOT about a perception then you still experience it but unconsciously.

There are two types of Higher-Order Theories, the first one being Higher-Order Thought (HOT) Theory and the second Higher-Order Perception (HOP). Both attempts to explain how consciousness emerges but differ in whether the higher-order state is a thought or a perception-like experience.

Higher-Order Thought (HOT) Theory – David Rosenthal

The HOT was first introduced by David Rosenthal, a philosopher and cognitive scientist, in the 1980s. Rosenthal explains it being a mental state, just like seeing red which then becomes conscious only if you have a thought about seeing red, in this case. He claims that consciousness requires higher-order thoughts that are distinct from first-order mental states. So, consciousness is not in the perception itself, but in the higher-order thought about the perception.

The prefrontal cortex is involved in self-awareness, metacognition, and decision-making and, according to David Rosenthal, it monitors and represents first-order sensory or cognitive states, creating higher-order thoughts that bring those states into consciousness. Brain damage to the PFC can reduce conscious awareness, supporting the idea that HOTs are needed for consciousness.

Higher-Order Thought theory Experiments

- Brain Damage & Blindsight Studies

  This experiment consists of seeing whether consciousness depends on HOTs or not. If they really do, then damage to the areas that generate HOTs, like the prefrontal cortex, should reduce conscious awareness while keeping first-order perception intact.

  For this study they used patients with damage to their primary visual cortex (V1). Patients with V1 damage report not seeing anything but only from the affected area. With this study they found that the patients can still respond to visual stimuli just like guessing from where a light is coming, without actually being consciously aware of seeing that light. This demonstrates that perception can occur unconsciously, which supports the idea that a higher-order thought is needed for conscious awareness.

HOT theorists believe that blindsight patients can still process visual information, but they do not have conscious awareness of it because they lack the mental representation so higher-order thoughts, that acknowledge seeing something. Their brain still detects and reacts to visual stimuli at a basic level, so the first-order processing, they still do not "think about" their perception, so they remain unaware of seeing anything. This supports the idea that consciousness requires more than just perception, because it needs a higher-order thought about that perception.

- Prefrontal Cortex & Consciousness
  This study was conducted in 2006 by Hakwan Lau and Richard Passingham. Their hypothesis was that if HOTs were really necessary for consciousness, then the prefrontal cortex should be involved in conscious experience. The study consisted of participants who were shown weak stimuli and were asked whether they saw them, for example, a really dim light flashed for a split second. Their brain activity was then measured using *Functional Magnetic Resonance Imaging* (fMRI). The fMRI is a brain imaging technique that measures changes in blood flow to detect neuronal activity.

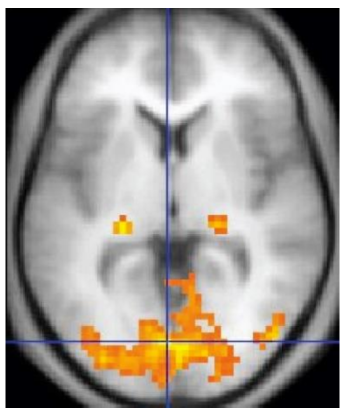


Figure 14 Functional Magnetic Resonance Imaging showing dorsolateral cortex activity

They found that when the participants consciously saw stimulus, the dorsolateral cortex (DLPFC) was active. When they did not report seeing it but still performed well in a guessing task, then the visual cortex was active but not the PFC.

In conclusion, without prefrontal cortex -generated HOTs, participants lack conscious awareness, so consciousness depends on higher-order thoughts which are formed in the prefrontal cortex

Higher-Order Perception (HOP) Theory – William Lycan

The higher-order Perception was introduced by William Lycan, a Philosopher in the early 1980s. His main idea is that instead of thoughts, consciousness actually arises from higher-order perceptions, that act like an internal type of mental sense that monitors our experience. So consciousness could be perceived as a self-scanning system that detects our own mental states. In conclusion, Lycan claims that consciousness comes from a second layer of perception, not from thinking about mental states. For example, when you see a red cherry but you do not notice it, then it is an unconscious perception, but when your brain "notices" the perception HOP happens and then you are conscious of it. Consciousness arises when the brain internally "perceives" itself, and that could happen in sensory regions of the brain but not just in the prefrontal cortex.

Higher-Order Perception (HOP) Theory Experiments

- Neural Monitoring of Sensory Perception
  This study was conducted by Stephen M. Fleming, Rimona S. Weil, Zoltan Nagy, Raymond J. Dolan, and Geraint Rees, and published in 2012. Their goal was to see if consciousness arises from higher-order perception, then sensory monitoring mechanisms should play a role in awareness. The study was called *Metacognition and Sensory Awareness*, and they used brain imaging techniques like fMRI again on people making visual judgements about faint stimuli.
  The participants were first shown faint images, just like dim flashes of light or masked images, and then they had to decide whether they saw something or if it was just noise, whilst researchers were recording their brain activity. With those brain images they saw that conscious perception correlates with activity in sensory areas, like the visual cortex, rather than just the prefrontal cortex. So the brain seems to "monitor" sensory signals, which supports the idea of an internal perceptual system, the HOP. This study supports the HOP theory because it suggests consciousness does not depend on thought but on internal perception-like mechanisms.

- Perceptual Awareness in Split-Brain Patients
  The split-brain experiments directed by Michael Gazzaniga and Roger Sperry in the 1970s. For this study they chose split-brain patients, because their condition allowed scientists to study how the two hemispheres of the brain function independently. If consciousness arises from higher-order perception rather than higher-order thoughts, then each hemisphere should still experience perception independently, even when disconnected from each other.
  The procedure was pretty simple and consisted of researchers presenting visual stimuli to only one hemisphere at a time by showing images to one side of the visual field.
  The key findings of this study were that each hemisphere could perceive a stimulus separately, although they could not communicate with each other. So, when an image was only shown to the right hemisphere, the left visual field, the person could not verbally describe it, because the language is in the left hemisphere. In spite of that, the right hemisphere was still able to recognize the stimulus, and the patients were even able to draw what they saw with their left hand (which is controlled by the right hemisphere). In other words, the right hemisphere processes the stimulus consciously and can act on it, even if it lacks verbal reporting. So, this proves that conscious perception does not requisite a higher-order thought about experience.

6.2.2. Higher-order theory of emotional consciousness by LeDoux

LeDoux's HOT theory is different from David Rosenthal's version of HOT, because he applies it specifically to emotions. He argues that we only feel emotions when higher-order brain areas, like the prefrontal cortex interpret lower-level bodily and brain responses, for example, heart rate increase or pupil dilation. So, his main idea is that emotions need conscious interpretation. LeDoux claims that emotion does not become feelings until the prefrontal cortex processes them and turns them into conscious experiences. This completely defeats the traditional views which focus on the amygdala and consider that emotions come from automatic brain responses.

The process suggested by LeDoux is divided into two main operations. The first-order processing consists of the amygdala detecting a threat and triggering an automatic response, such as heart racing, freezing. That happens even before we are aware of the threat. The higher-order processing consists of the prefrontal cortex (PFC) evaluating what actually is happening. It is only when the PFC recognizes the situation as fearful that we really feel fear. LeDoux's contribution to the HOT theory explains why we can feel fear even if there is no real danger present like anxiety. His theory separates unconscious fear responses from the feeling of fear and really highlights the role of the PFC in making emotions conscious. In other words, he says that emotions do not exist as "feelings" until the brain consciously interprets them, and that the amygdala triggers responses but the prefrontal cortex decides if a person actually feels fear.

The role of the amygdala in fear is pretty simple, it basically detects danger and controls autonomic fear responses. According to LeDoux the amygdala does not create the actual feeling of fear but that happens in the higher brain areas.

6.3. THEORY OF CONSTRUCTED EMOTION

The theory of constructed emotion is a theory in affective science which was proposed by Lisa Feldman Barrett, to explain the experience and perception of emotion. It was first introduced in the 2000s published in her 2017 book, *How emotions are made: the secret life of the brain.* The theory really challenges the traditional views on emotions as innate, universal responses. Instead, she proposes that emotions are not hardwired, but are actively constructed by the brain using past experiences, bodily sensations and the current environment.

Barrett introduced the *Theory of Constructed Emotion* to address what she terms the *Emotion Paradox* which, she claims, has confused emotion researchers for decades, and describes it like that: "…*People have vivid and intense experiences of emotion in day-to-day life: they report seeing emotions like "anger", "sadness", and "happiness" in others, and they report experiencing "anger", "sadness" and so on themselves. Nevertheless, psychophysiological and neuroscientific evidence has failed to yield consistent support for the existence of such discrete categories of experience. Instead, the empirical evidence suggests that what exists in the brain and body is affect, and emotions are constructed by multiple brain networks working in tandem."*

According to the theory, emotions are not fundamental pre-programmed elements of our psychology. Instead, they are interpretations conceptual labels that we hang on certain combinations of affect in certain contexts. When you experience terror, for example, what you actually feel is a specific set of physiological sensations tied to a certain affect such as having tense muscles, body being flooded with adrenaline or the heart pounding really fast. These affects might be caused by, per example, someone with a knife following you, or you are breathing in a higher-than-normal concentration of carbon dioxide. To make sense of these sensations, your brain rapidly processes contextual clues, about what might be causing them like features of the environment or memories of past experiences. The brain pieces everything together and assigns the whole mess with some emotional label as a description or name. That does not mean that terror does not exist but it does shift us away from the traditional views that terror is a hardwired emotional circuit in the brain waiting to be activated by something frightening. During this, fight or flight is still happening, so your body is preparing to handle a potential threat, but this emotion calls terror is a conceptual framing of the situation, also called an interpretation. In the constructed emotion theory, emotions are not just biological but also cultural, they are shaped by language, experience and the concepts available in your society.

Cultural phenomena's help us identify and categorize particular expressions of affect in specific situations. While there is significant overlap in emotional labels across cultures, there are also notable differences. For instance, English lacks a word for the pleasant, calm feeling that arises when something bad happens to someone who deserves it, but in German, this emotion is recognized as "schadenfreude". Once you learn the word and concept, you might find yourself experiencing that emotion more consciously as well. This is when the predictive processing model of cognition comes into play, it is the idea that our brain makes sense of the world through layers of prediction. At the lowest levels, there is raw sensory data which is often noisy and incomplete, while at higher levels, the brain refines this information into abstract concepts. Each layer filters and prioritizes information, ensuring only the most relevant details reach conscious awareness. For example, when your visual cortex expects an image to blur as your eyes shift focus, your brain pre-processes that expectation, so you never actually see the blur.

Barrett asserts that emotions are subject to the same prediction noise reduction sort of process. So, they feel immediate and urgent because your brain is scrambling to slap the most likely label on a wave of affect before it gets to your conscious mind. It is not unexpected or weird when it gets there. Interestingly this framework implies something that has been part of clinical psychology for a long time the power of reframing when someone gets into a pattern of negative emotions like sadness or anxiety, their brain is working hard to anticipate and categorize the bodily sensations associated with those states. However, by paying conscious attention to these sensations, it might be possible to reinterpret them in a more constructive way. For instance, when you are feeling nervous before a big important test and you are bouncing your leg, your body is clearly full of energy. Now instead of interpreting that sensation as anxiety, so negatively, you could reframe it as excitement. Barrett's theory suggests that the core difference between many emotional states is simply which predictive model the brain is using. If you can guide your brain toward a different interpretation, you may be able to shift your emotional experience in a meaningful way.

Constructed Emotion Theory Criticisms

The theory of constructed emotion has a lot of critics such as, the traditional theories that suggest emotions like anger and fear are biologically hardwired and universally expressed, whereas Barrett argues they are learned and shaped by culture. some research also shows that some emotions have specific neural correlates, per example fear is linked to the amygdala and disgust to the insula, that challenges the idea that emotions are purely constructed. Some other studies also show that babies already experience emotional responses without prior learning, which implies that emotions may be innate rather than entirely learned.

Lisa Feldman Barrett's Theory of Constructed Emotion still offers a challenge to the traditional views by emphasizing the role of prediction, culture, and experience in shaping emotions, it remains controversial.

7. Conclusion

The theory of emotions is a very interesting domain in which, as for neurosciences in general, concepts are partially valid and oppose each other. With this personal work, I have developed more knowledge first on the history of researches and second on the nervous system, in particular the limbic system and its components.

This subject confirms my willingness to continue studying sciences and follow my orientation into neurosciences or more general medical domain.

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