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Neural basis of emotions

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(Redirected from Emotion)

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In modern neurobiological terms, **emotions** are complex programs of actions triggered by the presence of certain stimuli, external to the body or from within the body, when such stimuli activate certain neural systems. Feelings of emotion, on the other hand, are perceptions of the emotional action programs. The (1) triggering systems, the (2) neural systems which execute the action program, and (3) the actions whose ensemble constitutes each emotion, were selected over evolutionary time and become available to each organism of a given species early in development thanks to that organism's genome.

The emotions are as ubiquitous in daily life as vision, or hearing, or touch, but only recently have they received due consideration from the brain sciences. Perhaps for that reason they have been the object of many misconceptions. For example, the word emotion is usually taken to mean both a specific pattern of behavior (the emotion, in the proper sense) and a mental state related to it (known as feeling). Moreover, it is often thought that the emotion proper is triggered by a feeling that precedes it. Current research indicates, however, that "emotions" and "feelings of emotion" are distinct aspects of a functional sequence that begins when an object or situation triggers a specific behavior — the emotion — which is followed rapidly by the perception of the changes related to the behavior — the feeling of emotion. Relative to the triggering cause, the functional sequence begins with actions and culminates in perceptions. The word emotion should be reserved for the behavioral component of the sequence; it should not be used to designate the feeling component.

Another misconception concerns the idea that emotions are irrational disruptions of consciously directed behavior. However, emotions are not necessarily contrary to reason. They are best seen as older forms of reason, assembled by biological evolution and not by conscious deliberation. They operate automatically and only in response to certain classes of circumstance. They are not the result of thinking through a problem and generating a solution (for background see Darwin, 1873; de Sousa, 1990; and Nussbaum, 2003).

Throughout evolution emotions have been instruments of life regulation, that is homeostasis. Emotions contribute to the survival and well-being of individuals and groups by providing organisms with a swift, automated means to circumvent dangers and take advantage of opportunities. This is true of animals and humans. In humans, however, emotions can clash with culturally acquired conventions and rules, in which case they may indeed be disruptive and less adaptive than consciously deliberated responses. In brief, although emotions have helped shape ethical behavior in the course of evolution, they are not a substitute for decisions informed by ethics (Damasio, 2003; Damasio, 2007).

The deployment of an emotion accomplishes several benefits to the emoting organism. The emotional action-programs achieve those benefits by producing extensive functional changes in varied sectors of the organism — for example, in the musculature of the viscera and of the skeleton, and in the chemical profile of the internal milieu — and by causing the organism to execute certain preset behaviors. Examples of muscular changes include tachycardia or brachycardia, gut contraction or dilation, and specific facial expressions and postures. Changes in the internal milieu can come from releasing chemical molecules into the bloodstream, as happens with the hormone cortisol in the case of fear. As for behavioral changes, the examples are numerous. The movements that lead an organism to concentrate on the object that triggered the emotion, whose ensemble is known as attention, and which results in the enhanced mental salience of the object, are present in most instances of emotion. The engagement of specific behaviors such as freezing in place, fleeing from a threat, or nurturing, are good examples of complex and specific behaviors that are part and parcel of the action-program of a certain emotion.

The range of emotions is wide but finite. In humans it includes the programs of fear, disgust, sadness, joy, anger, and surprise, as well as a group of simpler programs such as enthusiasm or discouragement, known as background emotions. It also includes a group of very complex programs, usually known as social emotions, such as embarrassment, shame, guilt, contempt, compassion, and admiration.

The triggering of each emotion requires the presence of an appropriate stimulus, an emotionally-competent stimulus, which initiates the execution of the actions in the program. The execution of each emotion is quickly followed by the respective feeling state provided the brain is complex enough to permit the mapping of internal states and a minimal level of consciousness. In situations in which there are multiple emotional-competent stimuli and multiple resulting feelings, the neat sequence of emotion to feeling may appear to be blurred.

Contents [hide]

The neural basis of the emotions

There has been major progress in elucidating the neural basis of the emotions and of emotional feelings. As a result of extensive animal and human studies, the best understood emotion is fear (Damasio, 1994/2005; Le Doux, 1996; Panksepp, 1998; Feinstein et al., 2010). Fear relative to external circumstances is triggered by the amygdalae, two sets of subcortical nuclei located in the depth of each temporal lobe. The amygdalae receive signals related to a certain situation, for example, a visually represented threat such as a looming shadow or an auditorily represented threat such as a high-pitched scream. When those signals have a suitable configuration, an appropriate context, and reach a workable threshold, i.e. when they are emotionally-competent, they activate nuclei in the hypothalamus and in the sector of the brain stem known as the periaqueductal gray. Working together those brain sites execute the requisite emotional actions — release of cortisol into the bloodstream, adjustment of heart rate, respiratory rate, degree of gut contraction, and fear-specific behaviors such as changes in facial expression and posture, and freezing in place or running away from danger. The ensemble of these actions constitutes the emotional state of fear. Thus, included in the emotional state are specific behaviors aimed at protecting the integrity of the individual, e.g. running away or freezing in place, and also a preparation of the organism meant to allow it to carry out those protective behaviors. When the situation is best handled by a flight response, the emotional state ensures that sources of energy are available in the blood stream and adjusts cardiac and respiratory functions so that they meet the metabolic needs ahead; the emotional state even provides for analgesia to offset the pain that might result from potential injuries. In situations best dealt with by staying in place as inconspicuously as possible, the preparatory actions are radically different since no muscular effort will be needed and, immobility is instead the desired goal. The selection of fleeing or freezing responses is made automatically although humans may override the natural selection and decide for one of the other option. This fine-tuned mechanism calls for the engagement of different cellular columns of the periaqueductal gray.

Fear caused by internal events, for example, the extreme pain associated with myocardial infarction or the development of acidosis associated with CO_2 inhalation, is probably triggered by chemoreceptors located subcortically, namely in the brain stem.

The emotion program of disgust is another good example of protection of the organism's integrity. Disgust is triggered from a small region of the anterior insular cortex when certain stimuli are present, for instance, the sight of decomposing food or body waste, as well as tastes or odors from decomposing organic matter. The sight of body-boundary violations, as in a wound with blood, also causes disgust. The actions that constitute disgust include a typical facial expression and, for example, the rapid expulsion of the potentially offending food. As a result the subject will not ingest a potentially toxic food and other subjects may also be alerted to the potential danger (Harrison et al., 2010).

In the social emotion of contempt there is a rejection of certain behaviors or ideas rather than an expulsion of toxic substances or their tell-tale signs. Contempt can be seen as a biological metaphor for disgust. Significantly, we refer to actions that cause moral revulsion as "disgusting," and the repertoire of facial expressions that accompanies a contemptuous judgment is similar to that of disgust. The advantages of contempt are apparent: the rejection of behaviors deemed dangerous to individuals or groups, and the social isolation of those who produce such behaviors.

Compassion is another emotion whose trigger region has been identified. The triggering site is located in the ventral and medial sector of the prefrontal cortex. When this region is activated by the sight of others facing a predicament, for example, an accident resulting in physical injury, facial expressions and even gestures meant to help the victims are rapidly deployed. Such actions benefit others and by extension the social group, but also result in personal benefits such as increased appreciation by others, gratitude, and thus enhanced reputation (Immordino Yang et al., 2009).

The neural basis of feelings

Recent progress in the elucidation of the neural basis of feelings has been just as remarkable. Historically, it was thought that emotion would occur when a causative object first triggered a feeling state as a result of which the body would be aroused emotionally. Feeling states elicited by a situation produced bodily manifestations, in the face and in the viscera. Late in the nineteenth century William James proposed to invert this sequence, as outlined in his 1884 paper: "Our natural way of thinking about these emotions is that the mental perception of some fact excites the mental affection called the emotion, and that this latter state of mind gives rise to the bodily expression. 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". James was proposing something along the lines of the current view. Each emotion is a collection of bodily actions so well differentiated that the overall perception of the particular action program of a given emotion yields a distinct pattern. There were early attacks on this position and claims that the body engagement was not differentiated enough to generate distinct feelings. It was said that the body component consisted of a non-specific arousal state, no different for fear than for sadness or happiness. Current evidence suggests, however, that the body state associated with each kind of emotion is distinctive and capable of supporting distinctive representations of emotion even if those representations are probably transformed by subcortical stations charged with transmitting signals from the body to cerebral cortex. The objections to James would not have found an audience if it were not for the unfortunate wording he used. When James stated that the feeling of the changed body is the emotion, he conflated emotions and feelings of emotions and opened the door to the arguments that undermined his position. Once it was possible to conceive of emotions-proper and feelings of emotion as distinctive components of a functional sequence, and once the mechanisms behind the triggering and execution of emotions gained clarity, the search for a physiological platform for feelings of emotion turned to somato-sensing brain regions. At the level of the cerebral cortex the insula offered itself as a main candidate and indeed a large number of studies have shown that numerous emotional feeling states, positive as well as negative, simple or complicated, activate the insular cortex. The fact that the insula is the main cortical target of signals hailing from the body's interior — the viscera and the internal milieu — is the likely reason for this differential activity (Damasio et al., 2000; Craig, 2002). But the neural basis of feeling states is not to be found only at the level of the cerebral cortex. We know now that complete destruction of the insula in both cerebral hemispheres does not abolish feelings, indicating that the feeling process probably begins at the level of the brain stem in nuclei which bring together at any moment information about the ongoing state of the body and can elaborate on that information. It has been suggested that the brainstem provides the most basic level of feelings — primordial feelings — whose modification would give rise to emotional feelings (Damasio, 2010). In brief, feelings of emotions are the perceptions of the action program that constitutes an emotion as it unfolds together with the salient representation of the causative object and with thoughts related to the situation. Organisms with simple brains need not perceive the unfolding of an emotional program for the emotional behavior to be effective. In organisms with complex brains, however, and with elaborate consciousness and memory, aspects of the feeling process are recorded and can be used for future planning and for optimized decision-making. In other words, feelings play a practical role in adaptive behavior and extend the advantages of emotions to the realm of conscious behavior. Feelings are not a useless reflection of the emotion process. Although the brain devices required to process emotions and feelings are put in place by the genome early in development, individual experience and learning introduce

variations in the performance of emotions. As a consequence there is a subtle customization that makes an individual's expressive patterns distinctive, in spite of their basic stereotypy. We laugh and cry with partially distinctive expressions. The fact that the emotional competence of objects and situations varies from individual to individual further undermines the possibility of genetic determinism. We all generate fear responses to a number of comparable situations, but each of us has learned to fear certain objects and situations that others will not. Individual experience alters the stereotypy that might result from genomic instruction. Finally, different individuals exhibit different degrees of emotional regulation, yet another source of customization of the emotion and feeling cycle (Davidson et al., 2010). Over the course of biological evolution, emotions have allowed organisms to cope with threats originating within the body or in the environment and to take advantage of opportunities related to nutrition or mating. Emotional action programs increase survival by delivering an advantageous standard response to particular circumstances in the absence of thinking and deliberation. For species with limited cognitive abilities this is a spectacular advantage. For humans the advantages vary with the circumstances. A rapid and comprehensive response can be beneficial, although on numerous occasions suppressing emotions and substituting a deliberated response constitutes the best response. But deliberated responses depend not only on an accumulation of factual knowledge and on the exercise of logic, but also on the past experience of emotional feelings relative to prior objects and situations.

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The basic emotion theory proposed that each emotion has its own dedicated neural circuitry that is architecturally distinct. For example, fear is a kind of emotion that produce subjective feelings through separate neural pathways of the central nervous system, or peripheral nervous systems (Cowen and Keltner, 2018). Therefore, studying the neural basis might be the best way to differentiate the basic emotions and probe into the number of basic emotions. Gyrus, Amygdala, Hypothalamus, Hippocampus Emotions • Emotional Experience • Emotional Expression • Input from senses • Behavioral output from somatic motor, autonomic and hypothalamus • Processed by cerebral cortex Theories of Emotion • James Lange Theory 1884 • Experience emotions IN RESPONSE to physiological changes in our body • Feel sad because we cry NOT cry because we feel sad • The emotion is the physiology Cannon-Bard Theory • 1927: Emotional experience. can occur independently of emotion expression • Transect animal spinal cord and emotional expression observed. • Removal or damage t