Psychobiology of Sadness: Functional Aspects in Human Evolution

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Abstract

Sadness is a basic and natural emotion, but it is perceived as unpleasant in comparison to other emotions as happiness, for example. Most scientific studies generally relate it to its pathological manifestation: depression. However, like any other emotion, it also manifests itself in the physiological and behavioral aspects, allowing for adaptive and interactional functions. Therefore, this article craves to provide information about the characteristics, determinants, evolutionary and adaptive function of sadness, as well as its neurobiological and facial expression - allowing a better understanding of its positive aspects in evolutionary terms. To do so, the literature search was carried out by means of queries to the PubMED and Google Academic bases, considering articles, books, dissertations and theses published without language restriction between the years of 1994 to 2018 to identify the state of production in this field of research in the last two decades.

Keywords: Neurobiology; Neuropsychology; Evolution of Emotion; Sadness; Behavioral Evolution

Introduction

Emotional systems comprise neural states that provide immediate means for the protection of the individual and that maximize the adaptation to events that require survival. The evolution molded set of basic emotions with distinct neural and physiological conditions, substrates for different adaptive functions [1]. This definition assumes that some emotions are universal, being present in all cultures and allowing greater recognition of facial expressions, for example, an important biological marker in human survival [1]. Table 1 presents the description of five basic emotions pointed by Paul Ekman and Eve Ekman in his psychological studies about emotions. In this sense, sadness as one of the basic and broad emotions among individuals has few studies that explore its psychobiological function, which is often associated with something negative or related to the depressive disorder.

Emotions	Description
Joy	Enjoyment includes peace and ecstasy, and the states of this emotion are triggered by feeling connection and/or sensory pleasure
Fear	All states of fear are triggered by feeling a threat of harm, and this emotion has both anxiety and terror
Sadness	Sadness has both disappointment and despair. The most states of this emotion are triggered by a feeling of loss
Disgust	It contains both dislike and loathing, and is triggered by the feeling that something is toxic
Anger	This emotion includes both annoyance and fury, and the states are triggered by a feeling of being blocked in our progress

Table 1: *Description of the five basic emotions.*

Font: Retrieved from Atlas of Emotion (http://atlasofemotions.org/)

Power and Dalgleish [2] point out that sadness is not a totally negative emotion, one of the most striking emotional experiences in humans compared to other basic emotions. Moll., *et al.* [3] describe that emotional experience can also be constituted by three other components: valence (positive and negative), alertness, and motor activation (approach and avoidance). Emotional valence can be verified through motivational systems, one associated with negative (aversive) emotions and another with positive ones (pleasant).

One can say that sadness is the emotion for which antecedent situations are distributed by the greatest number of categories compared to joy, fear and anger. The most frequently reported occurrences of sadness are: problems and/or death of friends, illness (own or other persons), problem and/or death of relatives, permanent separation of friends, failure in achievement situations, bad news (social context), bad news (mass media), temporary separation of friends, loneliness, end of pleasurable experience and general depression [4].

According to Lauwerijssen [4], researchers combined these situations into more consistent categories and found antecedents of sadness, such as: relationships, birth with anomalies/death, good/bad news, permanent separation, achievement, temporary separation. The most common antecedents provoking such problems are situations in relationships, particularly the end of them (in many cases by death) and issues related to the body, such as illness. Often, sadness is a response to a loss, potential loss or some unreached goal.

In the system of aversion, a source of stimulus of this nature generates negative affection, leading to a behavior of estrangement. In this way, one can observe the reason why emotions such as sadness are often associated with something negative, that is, because they are experienced in an unpleasant way in most situations by which they are evoked [3].

Moll., *et al.* [3] consider that visual stimuli can take on emotional content of positive or negative valence, characteristics that appear in a dimension different from the visual attributes of color, form and visual complexity. Thus, recent advances in functional neuroimaging have allowed progress in understanding the brain circuits responsible for various cognitive operations in humans.

A more specific model of cognitive emotion emphasizes the role of assessment in the development of sadness, the so-called Schematic Propositional Associative Analogical Representation Systems (SPAARS) approach. The starting point for sadness is an assessment of the loss or the potential for loss. The evocation of sadness can occur either as a function of the evaluation path (schematic model), automatic route (associative model), or through the propositional level. When sadness is generated by the automatic route is because something is associated with it, such as a particular place that has become linked to this emotion. When sadness is occasioned by the evaluation route, these are thoughts that normally leave the individual sad in a specific context [4].

Thoughts are caused by a holistic representation of self: an emotional self-image. This self-image is generated by thoughts about the world, of oneself and others. When a situation causes this model, sadness can occur. Finally, when sadness is generated by the propositional level, for example, a movie or a song, such a stimulus can make someone try it through evaluation or automatic route. Some studies will show that in stimuli such as music, there is a positive impact on mood, since this type of stimulation activates the hippocampus, amygdala and related structures of the medial temporal lobe, linked to emotions considered negative, such as sadness [4,5].

Thus, considering the theme: sadness, it was considered important to deepen its study to elucidate information about the characteristics, determinants, evolutionary and adaptive function of this emotion, as well as its neurobiological and facial expression - allowing a better understanding of its positive aspects and health effects intra and interpersonal.

A search was made in the literature through consultations with the PubMED databases (Service of the National Library of Medina of the United States for free access to Medline) and Google Scholar, considering articles, books, dissertations and theses published without restriction of language between the years of 1994 to 2018 to identify the state of production in this field of research in the last decades.

The terms used in PubMED were: sadness AND neurobiology, sadness AND function, sadness AND depression, sadness AND brain, and sadness AND emotional facial expressions. These descriptors were used to locate the publications together with the logical operator "AND" for the purpose of relating the terms. The Google Scholar search proceeded in the same way, replacing some of the descriptors for the Portuguese language.

The inclusion criteria adopted were: books, theses and dissertations, clinical trials, reviews and systematic reviews. Period from 1994 to 2018, containing relationship of sadness and its adaptive function; emotional expressions; anatomy and brain dimension during occurrence of sadness; pathological manifestation of sadness, depression. Exclusion criteria: conferences or publication of abstract only; specific treatment of emotions other than sadness; brain and other non-emotional aspects; brain circuits with pathologies other than depression; effects in the emotional process.

The following steps were followed: search and selection of studies, collection and selection of data, reading and description of data for writing. The objective of the study was to synthesize the main findings about the emotion of sadness in recent years, focusing on the following topics: evolutionary and adaptive function of sadness, neurobiology of sadness and pathological sadness.

Evolucionary function of sadness

To understand sadness from an evolutionary point of view, we must first consider the various emotions or the basic emotions. A common feature among different emotional states is that they are a response to external and internal signals, linked to positive rewards or some injury. Basically, they have evolved to make the individual survive in the best possible way. Fear, for example, is an emotion that helps the subject to avoid dangers, while pleasure encourages the quest to repeat previously experienced actions. Similar arguments can be made for other emotions such as anger, sadness and disgust. These basic emotions are characterized by distinct feelings and culturally universal expressions [1].

Darwin [6] considered that emotions have a central role in terms of adaptation, constituting important interactional tools for human survival. They make communication possible, provoking sympathy or antagonism in other people, showing the intentions of others more authentically than through verbal language. Basically, the function of emotions is to allow the individual to have plasticity and adaptability to the world, generating important inter and intra-individual functions. The interindividual functions allow a subject to provoke reactions in other entities (for example, emotional support). Intra-individual functions allow a person to adapt more easily to the situation by providing information about their psychological state for the purpose of comfort.

Attention is diminished to the external world in a person who is sad, therefore more intensified to inner aspects, which leads to energy conservation, and can be used to focus on solving the problem. This individual is usually pessimistic, socially withdrawn, overly realistic about personal skills, and has little initiative for new relationships or projects. On the other hand, such sadness allows us to focus attention on the most important things for the individual, and in periods of extreme loss or pain, would reflect more accurately on people who have meaning for themselves. These characteristics are of adaptive value when used to regulate one's own energy and carry out social investments [4,7].

As for the adaptive function of sadness, it is related to a motivational function, because as a situation or action causes the individual to become sad, in the future he will try to avoid it. In this way, other social and personal functions of sadness are emphasized: one is the strengthening of bonds through social support in order to lead to altruism, because it induces empathy or compassion in other people. In addition, an important personal function is linked to the increase in "self-focus," in which the individual tends to evaluate his priorities when there is some loss or when he thinks about the possibility of such an episode. This assessment can help change the balance of life by providing feedback on how the situation would allow a greater focus on the pursuit of its goals [4].

People can deal in different ways with sadness and a proper coping can contribute to good coping. Individuals who use the coping method such as meditation, for example, are not necessarily looking for enjoyable and distracting activities, but rather gain greater understanding of their problems and feelings as it involves self-focused attention. Meditation is characterized by self-reflection, as well as by a constant and passive focus on the emotions considered to be negative [4,8].

Because it is associated with problematic life circumstances, sadness favors the triggering of cognitive strategies that facilitate problem solving, because by thinking more meticulously about the social environment, the sad individual will probably find alternative answers to solve them [4]. In this way, Scherer and Wallbott [9] consider sadness as an emotion that helps in the recovery of a certain loss.

When a negative event can not be controlled, the feeling of sadness does not diminish. It is a universal response to the loss of a relationship and thus are considered phases of protest or despair of separation. The protest reinforces attachment, characterized by hyperactivity and vocalizations of distress, and that of despair facilitates detachment, characterized by decreased speech, resulting in introversion. In the scientific literature, three models of sadness in relation to these phases stand out: the caring model, the meeting model and the disengagement model. The models of care and meeting can be classified in the phase of protest and the phase of disengagement, of despair. The protest phase is designed to undo losses; the one of despair can be adaptive to the mourning and facilitates the detachment. The caring model (protest phase) promotes attachment strength through the help of other people. This is a final attempt to undo the loss or separation. The sad person, then, consciously works through a process of detachment from the beloved object [10].

When searching about the adaptive function of sadness in different cultures, one can observe several responses, for example, the tendency of the person to return inside and to move away from the others. When one turns to oneself, one understands that one tries to solve their problems and, when one moves out (environment), one is in the search of obtaining help from other people [4].

Sadness results from several types of losses, ranging from money to lack of success at work. Its biological and evolutionary function is associated with motivating the individual to recover what has been lost. It influences us in behaviors as a signal for requesting social support, which allows reflection and elaboration of situations through a prism not previously observed, provoking positive and fundamental changes. The loss of a loved one, for example, causes sadness and a finite period of suffering and grief, but most bereaved people do not develop clinical depression [4,7]. Therefore, sadness is an important adaptive emotion when viewed from an evolutionary point of view.

Neurobiology of sadness

Studies have related the medial frontal cortex to subjective emotions and self-awareness, in which results establish a direct link between neural activity and emotional experience in these regions. Areas of the brain that contribute to the classification of emotions predominate in the frontal (dorsal, ventral and rostral) and parietal regions. Other important regions are scattered over the surface of the cortex, especially in the frontal lobe, including the prefrontal cortex. It is important to note that no single region was considered unique for the classification of a single emotion, because instead of involving isolated regions of the brain, all basic emotions would be associated with pattern activation within a distributed network of cortical and subcortical systems. Limbic regions such as the amygdala, hippocampus and thalamus also form an important part of the network of emotions. In their experiments, Saarimäki., *et al.* [1] evoked six basic emotions and showed their brain activity, including sadness, in the face of some activities.

Sadness is expressed through physiological and behavioral reactions. In speaking of these reactions, we can distinguish between cerebral activity and peripheral nervous system (PNS). According to Freed and Mann [10], there is activity in more than seventy brain structures during sadness. The most prominent regions include the anterior and posterior cingulate cortex, prefrontal and dorsolateral cortex, ventrolateral cortex, temporal insula, areas of the basal ganglia and cerebellum. It is mediated by particular structures of the limbic system, involving activation in the hippocampus. It is still possible to observe that during the sadness, the oxytocin supply can be reduced and the dopamine is released, besides being closely associated with the increase of the activity in the thalamus and prefrontal cortex.

Scherer and Wallbott [9] examined self-reported physiological symptoms during sadness and provided information on the state of subjective sensation, duration, intensity, and expressive reactions, noting changes in breathing rate, heart rate (tachycardia), muscle tension, and sweating.

In a recent study, Lohani, Payne and Isaacowitz [11] have shown age-related changes in multiple response systems (experiential, physiological and expressive) in the reactivity and regulation of sadness. Emotional experience, physiological responses and behavioral facial expression were evaluated while the participants (sixty young and sixty elderly) visualized videos that motivated sadness. The results showed that, due to life experiences, the triggering content of sadness may lead to greater coupling between their experience and physiology in older adults than in young adults. Age is therefore an important difference factor to consider when examined within individual associations between emotional systems.

According to Lauwerijssen [4], research such as Schaller and Cialdini (1990) showed that the role of sadness is associated with slow and low activity responses. Individuals who are experiencing sadness tend to use data-based processing strategies, while people in a happy state tend to use top-down strategies (strategies oriented by theory). For this reason, therefore, it appears that sad people would be less influenced by stereotypes and categorical information and more prone to thoughtful and detailed analyzes of social information.

Facial expressions can also be used to define abnormalities in the processing of specific emotions. The way to classify these emotional expressions is based on their communication of potential threat, such as fear, anger; loss (sadness) and reward (joy). Several studies of fMRI (Functional Magnetic Resonance Imaging) reported amygdala hyperactivity in response to negative emotional reactions, or increased frontal activity during processing of negative facial expressions [12,13].

Although some research has used functional neuroimaging to focus on patterns of brain activation related to the analysis and perception of emotional faces, few have focused on the study of subjective emotional experience. However, it was observed that in general, unpleasant emotions caused a greater modulatory effect than pleasant ones, besides this effect being more pronounced in the visual areas of the thalamus and basal nuclei. When dealing with pleasant images and pictures presented, they appeared as potentiators in cortical activation when compared to neutral images, however, this effect was shown to be of a smaller magnitude compared to that provoked by the unpleasant images [3].

In terms of non-verbal behavior, Scherer and Wallbott [9] mentioned that when someone is sad, there are characteristics such as crying and sobbing, for example. This may be related to the relatively low level of control for this emotion and the need to communicate such an emotional state. Because it is a universal emotion, sadness has common facial expression and can be recognized in different cultures.

According to Reed and DeScioli [14], an expression of sadness on the different face communicated: as eyelids become oblique, eyes slumped, songs of lowered lips and sloping eyebrows, have a holding effect on the observers. In addition, Darwin [6] already played that during the sadness of the pelt, the flaccid muscles, the head remained in the box, the chest contracted, the lips, like cheeks and the jaw are depressed and the eagle becomes slow, often interrupted by deep sighs.

Studies such as that of Hills and Hill [15], emphasized the importance of humor in facial coding, especially sadness, because it causes a broader and deeper sampling strategy of facial features for the identification of expressions. According to these authors, individuals in a sad state do more assertively the recognition of facial expressions than people with cheerful humor, possibly by examining with caution the face of the other during their manifestation.

Tears or changes in pupil size can also serve as signaling in functional terms during a social interaction. In addition to its primary physiological functions, the change in pupil size may act to facilitate the perception of sadness and evoke social support [16].

Moll., *et al.* [3] point out that some data obtained from individuals with lesions relatively restricted to the amygdala produced reduction of emotional responses and selective deficiency in the recognition of facial expressions of fear, for example, demonstrating the importance of this area in the recognition and formation of negative affect.

In short, facial expressions of emotions assume a fundamental role in social communication, allowing the individual to respond empathically and understand how their actions affect others, encompassing various cognitive functions, where sadness has the function of influencing judgments, for example. In this way, difficulties in the perception or expression of facial emotions may considerably compromise the individual's social adaptation [17].

The pathological sadness

There is no doubt that sadness is an adaptive emotion. However, when it occurs in an excessive and prolonged state, it becomes pathological, that is, a depressive disorder in which it causes harm. Chand and Givon [18] point out that the characteristic of all depressive disorders is the existence of sad and/or irritable mood, accompanied by somatic and cognitive changes that significantly affect the individual's functions. According to the DSM-5, what differs between them are aspects of duration, momentum or etiology [19].

There are several classifications of DSM-5 depressive disorders, including disruptive mood disorder, major depressive disorder, persistent depressive disorder (dysthymia), premenstrual dysphoric disorder, specified and unspecified depressive disorder, as well as depressive disorder due to medical and substance/drug induced conditions. The latter are associated with too much substance and medication and various medical conditions that may resemble phenomena of depression [19].

The manual raises attention in cases of major depressive episode regarding the discernment of sadness and mourning, since, even though mourning may induce great suffering, it does not specifically cause an episode of major depressive disorder. When they occur simultaneously, depressive symptoms and functional impairment tend to be more severe, resulting in a worse prognosis when compared to mourning unaccompanied by major depressive disorder [19].

Some terms are usually associated with depression, with no clear distinction between them, such as sadness and distress/distress. Depression, however, varies over a prolonged period with sad mood, disrupting normal functioning in daily life, and may cause serious effects on health [19].

In their studies, Wakefield, Lorenzo-Luaces and Lee [20] dispute the DSM's most recent classification of major depressive disorder, with the hypothesis that the diagnostic criteria are not necessarily a disorder but a normal manifestation with respect to suffering. Certain depressive disorders listed in the Handbook may describe natural emotional reactions that are being inadequately pathologized. These studies reinforce that depression without significant complications would be closer to normal distress and sadness than pathological.

Pies [7] points out that sadness and depression are part of a feedback loop that reinforces each other, as in a vicious circle. When we experience everyday sadness, we are usually able to feel intimately connected with others. In contrast, when there is severe depression, we often feel marginalized and alone. In addition, the sense of time is noticed differently in sadness and depression. In sadness, there is a feeling that this will soon be over, and in severe depression there is a connotation that this will last forever, for there is distortion of temporal perception during depression, with a subjective feeling that time occurs more slowly. For the depressed person, there is no hope in the future and the past is an extremely negative moment.

Self-assessment about reality is interfered with in depression, where the individual can describe himself as "a total nothingness" or "complete failure." In the opposite direction, sad individuals usually see themselves as someone in their own right. Both the sad and the depressed person will describe feelings of sadness and loss, but a depressed person, however, bears only one suffering [7].

Through the presented results it is possible to consider important attention to the manifestation of sad natural humor, mainly as consequence to the diagnosis that can influence in the form of treatment of the individual.

Limitations and Suggestions

There were limitations on the low productivity in the last years of studies focused solely on the emotion of sadness and its neurobiology, considering the topics covered in this work. In this way, the selected search period was expanded to find papers that were relevant to the conclusion of this article. We suggest a systematic review and studies published in meta-analysis on the subject.

Final Considerations and Conclusion

From the analysis of what the research encompasses in relation to the emotion of sadness, key points of this work are highlighted for final considerations:
- All emotions have an evolutionary function, so that the human being develops in the best possible way;
- The main function of sadness is focused on evoking empathy as a means of obtaining social support and strengthening of bonds, as well as a motivational function to search for better future situations;
- Sadness also manifests itself physiologically, and in the brain there is activity in many structures such as the prefrontal cortex, thalamus, and hippocampus, which are part of the limbic system;

- The expression of emotions are important in terms of neurobiology so that they can communicate our subjective state;
- Sadness, as a basic emotion, can not be directly related to its pathology, depression, since it is a healthy manifestation in human evolution.

In this sense, it is concluded that sadness has received little attention in scientific studies, where depression is usually the most common subject of study. And, clearly, as addressed in this paper, one can perceive emotional sadness differently from depressive disorders.

As is generally perceived to be an unpleasant emotion compared to others, sadness experiences preterity in its research and research. However, like any other emotion, it also manifests itself in the physiological and behavioral aspects, allowing for adaptive and interactional functions. According to Saarimäki., *et al.* [1] individuals are generally aware of their current emotional state, which can assist in adjusting behavior in an adaptive way to better respond to the challenges of the environment.

In short, it becomes necessary to better understand the dynamics of sadness in the composition of humor. It should be emphasized that this emotion seems to collaborate for self-preservation and even to improve judgment and reflection of individuals in relation to meaningful relationships. By this potential it is emphasized importance in the deeper understanding of this emotion and borders with its pathological derivations.

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