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Brain and emotion: Cognitive neuroscience of emotions

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Cognitive neuroscience of emotions is a rapidly growing field. It focuses on the neural basis of emotional and social processes and strongly contributes to the better understanding of the biological basis of emotional processing. It integrates the results of neural and behavioral levels of analysis in healthy and clinical populations as well. The main topics and questions in cognitive neuroscience of emotions are the role of emotions in information processing, their neural basis for both cortical and sub-cortical levels, the perception of arousing and neutral stimuli, emotions and memory, the role of emotion in decision making, detecting emotional versus neutral faces, and individual differences in emotionality and their biological background. Brain imaging techniques (e.g., functional magnetic resonance imaging–fMRI) are used both for examining functional connections between emotion and perception, attention, memory and decision making, and for localizing specific psychological functions to specific brain areas. In this paper we discuss not only current research trends and methods but some important brain areas responsible for emotions (e.g., amygdala, anterior cingular cortex, prefrontal cortex) as well.

Key words: cognitive/affective neuroscience, International Affective Picture System (IAPS), individual differences, fMRI

Emotions are complex phenomena. They modulate and guide behavior as a collection of biological, social, and cognitive components. Theoretical assumptions emphasize one or more components, thus we can distinguish between cognitive theories (e.g., Clore & Ortony, 2008), social-constructivist theories (Averill, 1980; Bodor, 2004; Harre, 1986), and biological theories (Darwin, 1872/1963). Other authors, however, suggest an integrative view of emotions (Buck, 1985; Nábrády, 2006; Strongman, 2003). In this paper, we follow the biologically based theories and the cognitive/affective neuroscience approach. The aim of this paper is to give an overview of the historical roots, methods, and current research trends in the cognitive neuroscience of emotions. We present some human experimental data in order to demonstrate the relevance of using brain imaging techniques in the field of emotion. Before going into details with methodological issues and current research trends, we first illustrate some historical aspects of emotions.

Emotions, feelings, and affects are subjective states, thus it is not an easy task to quantify and examine them with objective methods. For this reason, research on emotion has largely been a neglected field in psychology. However, more and more interest has been dedicated to emotions for the last 30 years.

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In the history of psychology, the first "revolution of emotion" started in the 1960s when affective phenomena were implemented into a cognitive framework. Magda Arnold's (1960) concept of *appraisal* meant that we immediately and automatically evaluate anything that we encounter. This leads us to approach anything that we appraise as "good", to avoid what we find "bad", and ignore what is indifferent or "neutral". Appraisal is connected to perception and induces action. Schachter and Singer (1962) have suggested a two-factor theory of emotion in which emotions are interpreted as the interaction of physiological arousal and cognitive appraisal. According to others like Lazarus (1982, 1984), we are "evaluators" performing cognitive activity. We evaluate each stimulus that we encounter with respect to its personal relevance and significance. In sum, this first revolution has focused attention on the cognitive aspects of emotion (Scherer, Schorr, & Johnstone, 2001).

The second revolution occurred in the 1990s (Damasio, 1994/1996; Davidson, 1995; LeDoux, 1996; Panksepp, 1998) and has introduced new possibilities such as using brain imaging techniques in the cognitive sciences and in the research of emotions as well. New methods and equipment (e.g., ERP, fMRI, PET) are also suitable tools for studying emotions. Studies on the neural basis of emotions have been integrated into the discipline of cognitive neuroscience, and from the increasing number of publications we can conclude that the cognitive neuroscience of emotions is an emerging field.

The next section presents a brief history from the early neuroanatomical models to the birth of affective neuroscience. Afterwards, we examine the various techniques in the field of cognitive neuroscience. Finally, we will describe some current research trends with respect to human experimental results which highlight important brain areas that are responsible for emotions.

A HISTORICAL OVERVIEW FROM EARLY NEUROANATOMICAL MODELS TO MODERN NEUROSCIENCE

The roots of affective neuroscience go back to the early neuroanatomical models. Data came from introspection of healthy subjects and observation of patients with lesions or animal studies.

One of the earliest and most influential theories is that of William James (1884). According to his *peripheralist theory,* emotion is defined as the perception of specific bodily changes which result automatically from the appropriate stimuli. Imagine that you are walking in the forest and suddenly you notice a wolf. James states that, rather than your heart starts to pound because you feel afraid, you feel afraid because your heart is pounding. A more modern and modified peripheralist view is represented by Antonio Damasio. In his *somatic marker hypothesis* (Damasio, 1994/1996), he assumes that emotional stimuli elicit bodily changes ("somatic markers") whose central representation contributes to decision making.

James's theory has been challenged by many critics. In the first half of the 20th century, the results of Bard's (1934) and Cannon's (1931) studies with animals have demonstrated that rage reactions in cats are disrupted by brain lesions within the hypothalamus. If the hypothalamus is spared, however, rage reactions are still elicited even when the cerebral cortex is removed. On the basis of these observations, a *centralist theory* has been proposed in which the thalamus is a centrum for emotional perception and the hypothalamus mediates the emotional expressions (Morris & Dolan, 2004).

In his alternative assumption, Papez (1937) has described not one single center for emotions (such as the thalamus or the hypothalamus) but a neural circuit within several brain structures. The Papez circuit consists of the thalamus, the hypothalamus, the mamillary bodies, the cingular gyrus, and the hippocampus (Dalgleish, 2004). He has also suggested pathways among these structures where information is transmitted during an emotional state. However, there is less evidence that all streams are central to emotion. His work is a remarkable achievement for at least two reasons. On the one hand, it is an analogy for recent network models. On the other hand, he was among the first who have emphasized functional connections between cortical and subcortical structures. Papez was also a forerunner for current cognitive theories of emotion in the sense that emotional states have connections with higher cognitive processes, but the term "cognitive appraisal" has never been mentioned in his work.

The limbic system has often been mentioned as the central region for emotions. Its name comes from the Latin word "limbus" which means "border". The limbic system was first mentioned in 1878 by Paul Broca who described the gyrus around the brainstem. The limbic system consists of the Papez circuit extended with the septal areas, the nucleus accumbens, the amygdala and the orbitofrontal cortex (Greenstein & Greenstein, 2000).

The cognitive neuroscience of emotions and/or affective neuroscience

The concept was first used by Jaak Panksepp (1998) as "affective neuroscience". The cognitive neuroscience of emotions concerns the neural basis of emotional and social processes in humans and animals. It integrates molecular, neural, and behavioral levels of analysis in healthy and clinical populations as well (Davidson & Sutton, 1995; Lane & Nadel, 2000; LeDoux, 2000; Panksepp, 1998; Schmidt, 2003). It deals with the following topics: the role of emotions in information processing, their neural basis for both cortical and sub-cortical levels, the perception of arousing stimuli, emotions and memory, the role of emotion in decision making, detecting emotional versus neutral faces, and individual differences in emotionality and their biological background. We will discuss these topics in the fourth section.

METHODOLOGICAL ISSUES IN COGNITIVE NEUROSCIENCE

In the 19th century, the first mapping of brain functions was proposed by the phrenologist Franz Joseph Gall. He believed that the amount of brain tissue devoted to a cognitive function determined its influence on behavior. He assumed that increases in brain size would translate into measurable bumps on the skull. Many scientists began to dispute the validity of the phrenologists' theory and methodology. Consequently, mapping the brain through bumps on the skull had collapsed by the 1830s (Huettel, Song, & McCarthy, 2004).

In contrast to Gall's doubtful methodology, recent brain imaging techniques use a reasonable theoretical framework to describe changes in the blood-flow and metabolism of different neural activities during perceptual, motor, and cognitive mechanisms. Other methods examine electric and magnetic correlates of neural processes (Kéri & Gulyás, 2003).

Localization and networks

Functional brain imaging techniques were first used in order to localize sensory, motor, and cognitive processes.

Localization studies are important because psychological functions could be associated with specific brain areas. They not only provide information about the pathways of information processing in a normal population (i.e., about brain structures which are responsible for a specific function and about the temporal features of this function), but also provide information about impairments of a specific brain region and deficits in psychological functions. Functional magnetic resonance imaging (fMRI) studies not only generate maps of brain functions, but also identify functional relations among brain regions (Berman, Jonides, & Nee, 2006; Huettel, Song, & McCarthy, 2004).

Techniques and methods

Cognitive neuroscience offers methods for examination of one single neuron, as well as of the activity of neuron populations in vivo. The relevance of these techniques for research on emotions is that they provide "on-line" information from the functioning brain, detect fast changes and localize functions to specific brain structures.

Functional brain imaging techniques are fMRI and positron emission topography (PET). Although magnetoencephalography (MEG), electroencephalography (EEG), event-related potentials (ERP), and brain electric activity mapping (BEAM) are indirect imaging techniques, they are common in functional localization (see Table 1).

Different brain imaging methods are usually compared and contrasted in terms of their spatial and temporal resolution. In general, electrophysiological methods based on direct mapping of brain electrical dipoles (e.g., EEG) or magnetic dipoles (MEG) define the underlying cortical neuronal events in real time (10-100 ms), but provide relatively poor spatial resolution (many mm-cm). In contrast, fMRI and PET provide information on the increases in blood flow accompanying neuronal activity with relatively high spatial resolution (1-10 mm), but have limited temporal resolution because hemodynamic changes accompanying neuronal depolarization are much slower (Matthews, 2001).

Optical imaging methods (e.g., near infrared spectroscopy or NIRS) measure changes in cortical blood flow. They have poor spatial resolution and are restricted to study of cortical surface. In contrast, PET and fMRI allow mapping of neuronal activation deep in the brain. Metabolic imaging by magnetic resonance spectroscopic imaging (MRSI) or PET is also possible, but these methods have generally lower spatial resolution and poor temporal resolution (30s–minute). However, the specificity of the information they can provide is high (Matthews, 2001).

In sum, functional brain imaging can tell "what" and "where" something happens in the brain, while electrophysiological methods provide a better answer for "when" something happens. A combination of methods allows us to improve scientific knowledge of brain function.

CURRENT TRENDS IN COGNITIVE NEUROSCIENCE OF EMOTIONS

As it was stated in the introduction, the cognitive neuroscience of emotions deals with the role of emotions during cognitive processes (e.g., perception, attention, memory, decision making), its neural basis in the cortical and subcortical levels, the perception of emotional stimuli, and the individual differences in responding to emotionally evocative stimuli. In the following section, we discuss current research trends and describe some brain structures responsible for emotions (see Figure 1).

Relevant brain structures responsible for emotions

Amygdala. The amygdala plays a key role in emotional life. It is an almond-shaped structure situated bilaterally in the medial temporal lobe. Studies using modern brain imaging techniques have pointed out that the amygdala plays a role in emotional conditioning, in storing emotional events, and in coding emotional signals, especially the facial expression of fear (LeDoux, 1996).

Table 1
Techniques of localizing brain functions

Lesion	Stimulation	Registration of brain functions	
		Invasive	Non-invasive
– neurological disposition (corpus callosum agenesia) – disease (tumor, brain hemorrhage, sclerosis multiplex) – brain injury (accident) – surgical intervention (frontal lobotomy)	– observations during epilepsy – direct electrical stimulation during surgery – transcranial magnetic stimulation (TMS) – transcranial direct current stimulation (tDCS)	– single-neuron registration – microdialysis – optical intrinsic signal imaging (OIS)	– electric: EEG, ERP, BEAM – magnetic: MEG – functional: PET, fMRI – near infrared spectroscopy (NIRS)

Note. Adapted from Gulyás, 2003; Toga & Mazziotta, 2002. EEG = electroencephalography; ERP = event-related potentials; BEAM = brain electric activity mapping; MEG = magnetoencephalography; PET = positron emission topography; fMRI = functional magnetic resonance imaging.

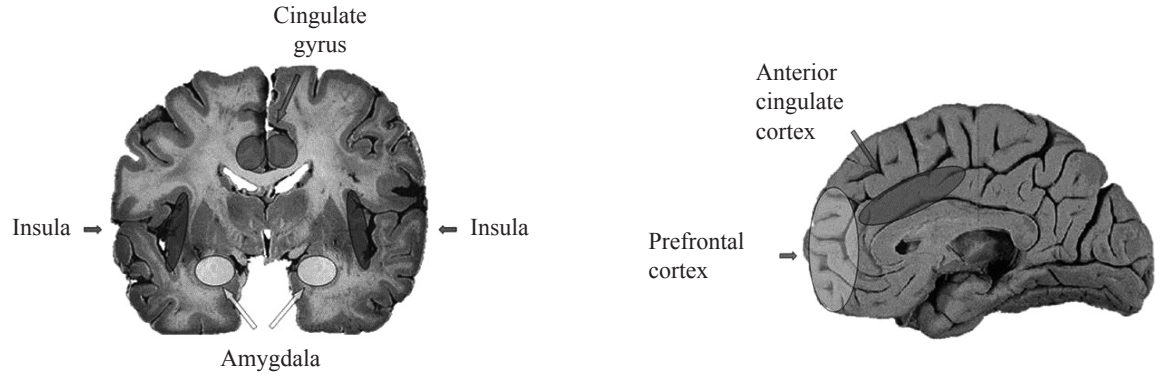

Figure 1. Brain structures responsible for emotions.

Several researchers disagree with the fear-specific function of the amygdala and suggest that it plays an expanded role in emotional detection. Breiter and colleagues (1996) have assumed that the amygdala might have an expanded role besides identifying fearful stimuli. They assume that the amygdala is sensitive to detection of pleasantness/unpleasantness (valence) of stimuli in addition to features specific to emotional states such as fear, disgust, sadness, and surprise. This has been an inspiring idea, and a new bidimensional model has emerged from it. According to this bidimensional model, scientists dispute whether the amygdala is sensitive for pleasantness or unpleasantness of a stimulus (valence-sensitivity) or if the amygdala responds to the arousal evoked by a stimulus.

Paul Whalen and his colleagues (2001) have tested the "valence hypothesis" in an fMRI experiment. In this experiment, participants viewed fearful, angry, and neutral faces. Brain activity in the "fear vs. neutral", the "anger vs. neutral", and the "fear vs. anger" condition were compared. Previously, Whalen hypothesized that an angry face shows more information about the source of threat, while a fearful face mirrors more ambiguity regarding the direction of danger. Consequently, Whalen expected more amygdala activity during the detection of anger compared to the detection of fear. In the "fearful vs. neutral" and the "angry vs. neutral" conditions, that is, during perception of stimuli with negative valence, ventral amygdala became more active. In the "fearful vs. angry" condition, the dorsal amygdala was activated. More recent studies (Ewbank, Barnard, Croucher, Ramponi, & Calder, 2009), however, have pointed out that the amygdala can also be activated when the arousal level is low (e.g., sadness). This is a turning point in research related to the amygdala, because its role is becoming associated with the perception of those stimuli that are relevant for the organism (Sander, 2009).

FMRI results from our lab have strengthened this assumption, too (Hermann, Deak, Papp, Révész, & Bereczkei, 2010). Twenty healthy subjects were presented emotionally evocative and neutral pictures. Inside the scanner, they had to rate the subjective level of pleasantness on a 9-point Likert scale. Brain activation to self-relevant stimuli (positive, negative, and social neutral) was compared to neural response to self-irrelevant neutral pictures (e.g., household objects). Irrespectively of the pleasantness and arousal ratings, amygdala activation was found (see Figure 2). This means the amygdala responded to positive, negative, and neutral but socially relevant stimuli when subjects had to give assessment for the stimuli. Hereby, we do not suggest that the amygdala would be the only brain structure for rating the relevance of a stimulus. Other brain regions, like the insula, the orbitofrontal cortex, and the anterior cingulate gyrus also play a crucial role.

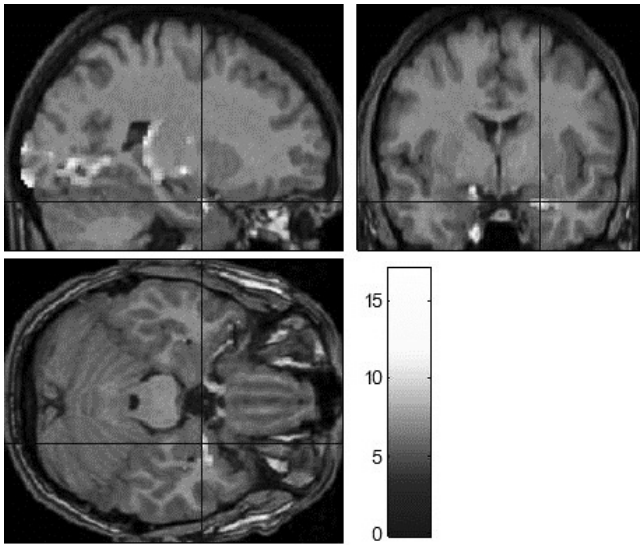

Figure 2. Brain activation to emotionally relevant stimuli compared to irrelevant neutral pictures: the amygdala (24-2-24; $T = 7.17$, $p < 0.05$, FWE) responded to negative, positive, and socially relevant stimuli (neutral faces) compared to non-social neutral pictures (e.g., household objects).

In sum, recent brain imaging techniques have helped to clarify the role of the amygdala in emotion detection, and that its function is non-specific to fear, but might be sensitive to the arousal of the relevance of the stimulus. The amygdala might influence cognition by modulating sensory thresholds that regulate both information processing and guiding the organism's attention to the emotionally relevant stimuli.

Insula. The insula is a multimodal sensory region in Brodmann areas 13 and 14. Its activation can be detected during emotional induction when an emotional event is recalled or imagined (Phan, Wager, Taylor, & Liberzon, 2002). It also coordinates sensomotor responses to unpredictable, threatening stimuli (Szily & Kéri, 2008) and to cognitive tasks (Reiman et al., 1997). The insula not only plays a role in the identification of special types of emotions such as disgust from faces and the perception of unpleasant tastes (Stark et al., 2007), but Critchley, Wiens, Rotshtein, Öhman, and Dolan (2004) have argued that the insula also mediates emotions to reach the level of consciousness through arousal. Others, like Reiman et al. (1997), have assumed that the insula plays a signaling role which alarms the organism during a state of threat. This assumption can explain why both self-induced and recalled guilt, shame, sadness, and also unpleasant stimuli activate the insula (Lane, Reiman, Ahern, Schwartz, & Davidson, 1997; Lane, Reiman, Bradley, et al., 1997).

Anterior cingular cortex. The cingulate gyrus belongs to the limbic system. Functionally it can be divided into two parts: its dorsal subdivision associated with cognition in the Brodmann areas 24 and 32 (the cingulate motor area), and its ventral subdivision associated with affective processes in the Brodmann areas 25, 32, and 33. Its rich anatomical connectivity provides a neural background to evaluate the behavioral relevance of stimuli and the influence of autonomic and motor responses (Morris & Dolan, 2004).

According to Bush, Luu, and Posner's study (2000), the anterior cingular cortex plays a key role in emotional monitoring and evaluation. It integrates autonomic, emotional, and attentional information in order to regulate the emotional states with respect to the ongoing emotional or cognitive priorities and goals and to select appropriate responses. In the case of a conflict between ongoing and adequate activity, the anterior cingular cortex can alarm the prefrontal cortex to modify the ongoing behavior.

Blair, Morris, Frith, Perrett, and Dolan (1999) have demonstrated the function of the anterior cingular cortex in their PET study. With computer graphical manipulations they produced a range of six intensity levels of an individual face depicting an emotional facial expression (e.g., fear) and a neutral face. On this intensity range, a neutral face was seen on one end (100% neutral face, 0% emotional face), an emotional face on the other (e.g., 100% sad face, 0% neutral). Pictures were presented one-by-one to participants while recording their brain activation. The intensity of the emotional expression correlated with a neural response in the anterior cingular cortex and the orbitofrontal cortex – that is, the higher the level of expressed intensity on a face, the stronger the reaction elicited in the anterior cingular cortex.

Orbitofrontal cortex. The cortex on the ventral (orbital) surface of the frontal lobe is highly developed in primates and is comprised of Brodmann areas 11, 12, 13, and 14. It consists of Brodmann areas 10, 11, and 47 in humans. The anatomical connectivity gives it the potential to integrate sensory information from different sources, to modulate sensory and other cognitive processing via feedback connections, and to influence motor and autonomic output responses (Morris & Dolan, 2004).

In an fMRI study (Elliott, Friston, & Dolan, 2000) subjects received either reward or punishment in a card game. Different brain structures were found to be active for reward compared to punishment. The orbitofrontal cortex, however, has shown valence-independent activity. It has responded to both high amounts of reward and high amounts of punishment. One possible explanation (Rolls, 1999, 2000a, 2004) suggests that the orbitofrontal cortex is responsible for learning the emotional and motivational value of stimuli.

In regard to frontal brain areas, a lateralization hypothesis is often cited (Davidson, 1992a, 1992b, 1995, 1998). It declares that left prefrontal regions might be connected to approaching behavior and maintaining goals, whereas right prefrontal areas might be associated with behavioral avoidance and withdrawal. Interestingly, depressive people's stronger negative emotions might be due to hypoactivity in the left prefrontal cortex (Davidson, Pizzagalli, Nitschke, & Putnam, 2002).

Individual differences in affective reactions: brain, behavior, and personality

Through behavioral, electrophysiological, and fMRI studies Peter Lang and Margaret Bradley have demonstrated the existence of two motivational systems – behavioral approach and behavioral avoidance (Bradley & Lang, 2007; Lang, Bradley, & Cuthbert, 1990). All emotional states can be described by two dimensions: *valence* and *arousal*. The valence dimension represents the pleasantness/unpleasantness of a stimulus, while the arousal dimension shows the level of intensity. The patterns of emotional states evoked by emotionally arousing sounds, pictures, and texts have the same boomerang-shape in a two-dimensional space. In the two-dimensional space, pleasant stimuli are located in the upper half, unpleasant stimuli are in the bottom, while neutral stimuli can be found at the left side. Neutral stimuli have low ratings in arousal and medium ratings on the pleasure scale.

The boomerang-shape distribution seems to be universal. In some cross-cultural studies, we compared the

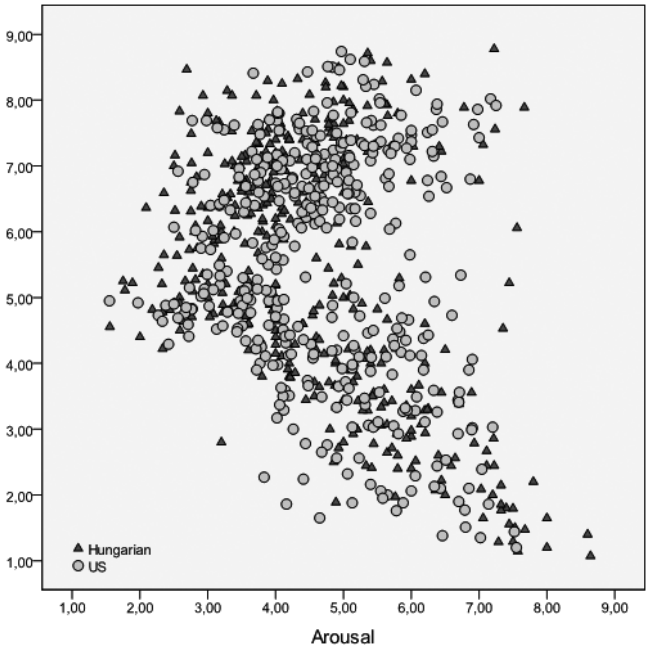

Figure 3. Distribution of IAPS pictures in the affective space determined by valence and arousal dimensions from all subjects in the Hungarian sample compared to the US ratings (adapted from Deak, Csenki, & Révész, 2010).

North-American standards to Hungarian, Polish, Flemish, and Brazilian data (Deak, Csenki, & Révész, 2010; Várhegyi, 2010). The ratings and distribution were similar in the Hungarian sample as well (see Figure 3). We can conclude that IAPS stimulus sets and rating procedures are suitable for measuring human emotional reactions and for searching for specific response patterns among individuals or clinical populations.

Many terminologies exist for bidirectional descriptions of behavior (Corr, 2002; Gray, 1994; Lang et al., 1990). Gray (1994) has differentiated a behavioral activation system (BAS) and a behavioral inhibitory system (BIS). Rolls (2000b) has categorized behavioral responses into two groups: responses to rewarding (positive) stimuli and to punishing (negative) stimuli. Considering this, we may ask if there are patterns of individual differences within these two systems (approach/activation vs. avoidance/inhibition).

Examining individual differences in emotional reactivity is based on the fact that an emotional stimulus can induce a wide range of responses from the participants. When considering the question of individual differences, one must specify the response system in which scientific exploration occurs. Besides individual differences in subjective evaluation, there can be differences in brain activity as well (Hamann & Canli, 2004). For example, an individual may have a low threshold for the elicitation of subjective feelings (which can be measured by self-reports), but may also have a relatively high threshold for the elicitation of physiological changes. Other parameters which differ across individuals can be the peak of emotional response, the rise time to peak, and the recovery time of expressive behavior (Davidson, 2000).

Schaefer and colleagues (2002) asked their participants to regulate their reactions to negative pictures in order to maintain negative affective state for a while. Greater amygdala activation was found among people who gave higher scores on the negative emotionality scale.

Richard Davidson (1992b, 2000; Davidson & Irwin, 1999) has used the phrase "affective style" to refer to the broad rubric of characteristics along which individuals might differ in their reactivity to emotionally provocative events. Large individual differences were found in baseline electro-physiological measures of prefrontal activation. These individual variations were associated with differences in affective reactivity. Extreme left-frontally activated subjects were compared to extreme right-frontally activated participants in an MRI study to determine if there were any morphological differences in anatomical structures. Results showed no regional volumetric asymmetry between the two groups. These findings suggest that the individual differences in the prefrontal brain activation were likely functional and not structural (Davidson, 2000).

Extreme left- and extreme right-frontally activated subjects showed significant differences in both self-reported positive and negative affects, and brain activation pattern. Left-frontally activated subjects reported more positive and less negative affects than their right-frontally activated counterparts (Tomarken, Davidson, Wheeler, & Doss, 1992).

FMRI correlates of personality traits (e.g., extraversion and neuroticism) are also an interesting direction in the cognitive neuroscience of emotions. In an experiment (Canli et al., 2001), participants had to passively view positive and negative pictures in the MR scanner. Results converged to previous behavioral studies: scores on extraversion correlated with brain activation responding to positive stimuli, and not to negative stimuli. Moreover, neuroticism correlated with brain activation in left temporal and frontal regions in response to negative pictures. Canli's further findings showed that the amygdala of people with a higher score on extraversion became more active to happy faces (Canli, Sivers, Whitfield, Gotlib, & Gabrieli, 2002).

In a recent fMRI study (Papp, Deak, Hermann, Révész, & Bereczkei, 2010), we tested J.A. Gray's (1994) neuropsychological theory of personality among healthy volunteers. Subjects were divided into sub-groups on the basis of their scores on behavioral activation system and behavioral inhibitory system. The behavioral activation system is responsible for reward anticipation, goal-directed behavior, and

approaching, while anxiety, inhibition, and avoidance derive from the behavioral inhibitory system. High behavioral inhibitory system subjects' brain activity was significantly stronger for negative stimuli compared to low behavioral inhibitory system subjects. It means that individual differences can modulate the emotional information processing. In our study the anterior cingular cortex, the orbitofrontal cortex, and parahippocampal areas were found to play an important role.

SUMMARY

Emotion research has been a neglected field until the last 30 years. Due to the emergence of cognitive neuroscience in the last 10 years, scientific inquiry about emotions has dramatically increased. Brain imaging techniques have provided new methods and experimental paradigms with which we can find specific brain structures and neural networks that generate and maintain emotional states, and take part in emotional processing. We can also get information about the relationship between emotion and cognitive processes (e.g., perception, attention, memory, and decision making), as well as the consequences of brain impairment on one's social-emotional behavior.

The cognitive neuroscience approach to emotions or the affective neuroscience with its strong biological identity can integrate all of the abovementioned questions and find answers to them with its special methods. Both the electrophysiological methods (e.g., EEG, ERP) with high temporal resolution (msec) and the functional brain imaging methods with high spatial resolution provide details about "when", "where", and "what" happens in the brain during psychological processes.

In light of this, it is also necessary to point out some of the disadvantages of the brain imaging methods. For example, the scanning procedure in an fMRI study is loud. To reduce acoustic noise, fMRI participants should always wear ear-plugs or headphones. The most common risk when participating in an fMRI study is claustrophobia. If a subject appears to be more than mildly anxious, the experiment should be stopped immediately. Finally, the costs of an fMRI study are relatively high, therefore it is necessary to not only construct an efficient experiment, but also to use previously collected behavioral data from pilot studies to increase the likelihood of experimental success and save money.

In this paper, we have summarized not only the definition and methods of affective neuroscience, but also its current research trends. One prominent field is emotional information processing. Many researches focus either on face perception, since facial expressions are important sources of information about the internal state of the organism (e.g., joy, disgust, being alert or relaxed), or to the perception of emotionally evocative stimuli as they indicate information about the external features of the environment (e.g., direction of threat, emotional atmosphere in a social context). This trend mainly follows a categorical approach in which discrete emotional categories are defined (e.g., anger, sadness, fear, happiness).

Another trend follows a dimensional approach. In this frame, there are generally two dimensions (valence and arousal), and emotional states are identified as "coordinates" in the two-dimensional space. The key question for this research trend is whether valence or arousal is more prominent in the appraisal of emotional stimuli, and which are the common and different brain structures that respond to valence and arousal components.

Regarding the future of affective neuroscience, we have positive expectations. Many questions are still open. Much less is known about positive emotions than about negative emotions. More studies should be done about the neural background of the subjective component of emotions (feelings). Moreover, an emerging field is the role of emotions in decision making. More data should be collected about the specific role of the brain structures. Recent studies have directed the attention to the role of cerebellum in cognitive and affective processes (Gordon, 2007; Schmahmann & Caplan, 2006; Schutter & Van Honk, 2005; Turner et al., 2007). Finally, new methods, procedures, and experimental designs are expected to broaden the set of tools.

In this paper, we use the term *affective neuroscience* and the *cognitive neuroscience of emotions* as synonyms. Some may argue that emotions are not the topic of cognitive research. Others (Lane & Nadel, 2000; LeDoux, 2000), however, disagree with using the term "affective neuroscience". In their critiques, they argue that the neuronal language of cells in the nervous system is universal-that is, action potentials are evoked similarly both in cognitive and affective processes. Thus, the term "affective neuroscience" leads to redundancy and a useless distinction between affective and cognitive neuroscience. We would like to emphasize, however, that it is neither the question of the relevance of the neuroscientific approach to emotions nor of the emotion's role in information processing. But, this is a debate showing how a new approach is being integrated into the scientific discourse. It defines itself as affective neuroscience and/or the cognitive neuroscience of emotions. Instead of analyzing the latest form of the classical cognition-emotion debate, we would like to point out the fact that emotions are within the scope of scientific inquiry due to new methods offered by the neuroscientific approach.

In conclusion, we state that the affective neuroscience is a rapidly growing field that strongly contributes to the better understanding of the biological basis of emotional processing. Brain imaging techniques are used both for examining functional connections between emotion and perception, attention, memory, and decision making, and for localizing specific psychological functions at specific brain areas.

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