A COGNITIVE NEUROSCIENCE PERSPECTIVE OF EMOTIONS

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The above noted work is submitted to the School of Bioscience at the University of Skövde, as a final Master project toward the degree of Master of Science (M.Sc.) in Cognitive Neuroscience. The project has been supervised by Judith Annett.

I, Ioana Anca Lymeropoulou, hereby declare that:

1. The above noted work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

2. The above noted work is the result of my own investigations, except where otherwise stated. Where corrections services have been used, the extent and nature of the corrections have been clearly marked.

Ioana Anca Lymeropoulou 11th June 2015

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Signature

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Date
A Cognitive Neuroscience Perspective of Emotions

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Abstract

Emotions have a remarkable capacity to mobilize an individual and shape a person’s behavior in order to ultimately lead to a higher wellbeing. The importance of emotions is further emphasized by pathological cases of people who suffer from an inability to normally regulate their emotional life, such as people who suffer from major depression disorder (MDD), eating disorders, or borderline personality disorder. Given the central role emotions play in our lives, it is very easy to understand the great interest cognitive neuroscientists have in this research field. Emotions have been approached in the last decades from different angles and as such, distinct theories arose. The goal of this study is to give a comprehensive overview of the emotion theories that exist, with a focus on three of the fastest developing cognitive theories of emotions: Frijda’s action-readiness, Russell’s core affect and the communicative theory. Additionally, the neural correlates of emotions will be discussed, focusing on the role of amygdala in the negative emotion of fear. Neuroimaging studies that reveal a correlation between the amygdala and emotions, fear in particular, will be described. Given that the ability of self-regulation is crucial for the achievements of our aims and goals, fMRI studies designed to investigate neural the underpinnings of emotion regulation will be presented. The process of cognitive reappraisal will be used to point towards the brain regions that act as down-regulators for the activity of amygdala while processing negatively valenced stimuli.

Key words: Emotions, Emotion Regulation, Cognitive Theories of Emotions, Fear and Neural Correlates, Amygdala, PFC, fMRI, PET studies.

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General Background

There is a great interest in the scientific world in studying emotions in the fields of neuroscience and psychology. A ScienceDirect database search for the papers that contain the word “emotions” in the title dating from 1995 until early 2015, yields more than 3300 citations. Why are emotions so much studied these days?

People have an enormous ability to adapt to a great diversity of situations. This can be done at least in part through the regulation of emotions. Examples of such regulation are staying calm in front of a dangerous situation, reducing stress levels in stressful circumstances or feeling happy when achieving something important. Emotions guide our actions in different circumstances, such as when expressing gratitude towards people that have brought happiness in our lives, or if we go the other direction, emotions enable us to avoid danger and keep us calm through stressful situations.

Emotions, moods and preferences are very often termed affects, but differences between emotions and feelings exist. We refer to emotions as to brief and intense experiences while feelings are referring to low-intensity and more prolonged experiences. While some of us define an emotion as “a feeling that you get when…” (Gazzaniga, Ivry and Mangun, 2014), therefore using the terms “feeling” and “emotion” interchangeable, scientist draw a line between these two. The same was claimed by William James who wrote in the popularized distinction classification, that a feeling is the subjective experience of the emotion while bodily responses are the emotional expression. But why should we care to study emotions in the first place? If we think about it, emotions mark the most important events in our lives are responsible for the connection between outer events and inner concerns, because without emotions there would be no life at all and because emotions makes us who we are. Emotions are extremely important because they help to optimize the intake of the sensory stimuli, they guide the process of decision making, and allow us to redirect our
attention and improve episodic memory (Gross, 2014). Both positive and negative emotions
permeate every aspect of our lives, being modulated by a wide variety of factors: our
behavior, biological states, environment, the people we socialize with and the way we are
thinking, and redirecting further our behavior. A famous quote that nicely resembles the
importance of emotions in our life was written by the famous American writer and lecturer
Dale Carnegie, “When dealing with people, remember you are not dealing with people of
logic, but creatures of emotion”. Understanding how the brain is able to generate emotions
will enrich our understanding of who we are but to give a definition or a general accepted
tory of emotions has turned out to be very tricky. Once, an unknown author said that “there
are as many theories of emotions as they are emotion theorists” while Fehr and Russell
claimed in 1984 that everybody have an opinion about what an emotions is, but at the end of
the day no one can provide a clear definition.

From a common sense perspective it seems that sometimes emotions bias our
decision-making in a bad way, therefore leading to ill directed behaviors. An example as such
is deciding for a non-respectful response when someone is insulting us. Other more
pathological examples might constitute bad eating behavior or an ill-directed spending
conduct when one feels sad. But science has taught us that emotions are necessary if we want
to live a healthy, happy and fulfilled life (Damasio, 1994). In 1994 Damasio outlined the
positive roles emotions play in human life by making use of clinical cases of people with
brain damage (Damasio, 1994). In 1848 Phineas P. Cage suffered a work accident that left
him with a badly severed prefrontal cortex. Elliot was another patient that had his prefrontal
cortex removed due to a brain tumor. It was observed that both patients were unable to
manage their emotions; they were unable to plan and had been severely impaired in their
decision making abilities (Damasio, 1994). Hence, it seems that emotions do play a role in
our life, and a quite an important one as observed from pathological cases, and also from
reasoning and decision-making studies which emphasize the impact and importance of an emotional life. Furthermore, it is also observable from our lives that experiencing positive emotions speeds up the process of healing during times of pathological distress, while negative emotions keep us away from danger, therefore leading to healthy outcomes which make them also ‘positive’. While the science of emotions is rapidly progressing it is reasonable to point out that there are a great variety of scientific branches that approach emotions. One important and relatively new field of research emerging from basic psychology is positive psychology founded by Dr. Martin Seligman back in 1998, a branch that also deals with people’s emotions in order to improve an individual’s quality of life, as well as the quality and wellbeing of the society we are living in.

To conclude, emotions differ from feelings and the study of emotions is highly important given the impact they have in our lives.

**The Aims of the Thesis**

Given this high variety of approaching angles, the aim of this theoretical thesis is to give a comprehensive up-to-date literature review on the most well-known researched theories of emotions. Considering that all people have the inborn ability and tendency to look for development and personal growth, many research studies focus on understanding how we can regulate our emotions and how emotions regulate us. Emotion regulation studies are driven by goals such as improving individuals’ wellbeing. This study will discuss the underlying neural mechanisms that support emotion regulatory strategies, while most recent available scientific data will be reviewed. The role of the amygdala as the primary subcortical region that correlates with the emotion of fear is exposed here while describing recent neuroimaging studies. Additionally, based on reliable neuroimaging results, this study will discuss prefrontal cortical regions found as potential candidates for down-regulation of amygdala’s activity in the process of cognitive reappraisal.
Theories of Emotion Generation

What are Emotions?

Emotions are considered the cause, effect or simply mediator factors on processes such as perception, learning and attention. The study of emotion has been approached from many different angles either by neuroscientists, philosophers, psychologists, media, computer scientists, to name a few (Kaklauskas et at., 2011; Peperkorn, Diemer & Muhlberger, 2015; Zachar, 2014). Given the importance of emotions in different psychological disorders the high interest observed in this line of research is not surprising. Although the study of emotion crosses disciplinary boundaries we do not yet have an answer for the eminent question William James put back in 1884: “What is an emotion?” This might be due to the fact that scientists have a great repertoire of ideas for how emotions are born. Is there a generally accepted definition of emotion or are there many different ways to think about emotions? The truth is that many theories of emotions exist, starting with Darwin’s theory of the evolution of emotions, to James-Lange and Cannon-Bard physiological theories, and to the cognitive theories. The common factor among these theories is that they assume that an emotion consists of several steps following the perception of the emotion-triggering stimulus. These steps include a physiological response to the stimulus, a behavioral response and the subjective experience or the feeling (Gazzaniga et al., 2014). Emotions are therefore seen as a set of component processes (Scherer, 2005). The stimulus can be either an external event such as a natural phenomenon or other people’s behavior, or internal events like memories, imagination or hormonal changes (Scherer, 2005). It is also possible that our own behavior, as is the case with guilt or shame, can be the triggering event for emotional processes (Scherer, 2005). When scientists try to categorize emotions they usually tend to follow an approach that is either psychoevolutionary, psychophysiological, neurological or a dynamic. However, perhaps these theories are not so different after all and finding their common
Physiological Theories of Emotions

**James-Lange theory.** According to the James-Lange theory, after the perception of a stimulus, physiological reactions take place (e.g. accelerated heart rate or breathing, sweating, etc.) after which an automatic and possibly unconscious interpretation of the above described physiological responses occurs. This automatic and nonconscious interpretation gives rise to the subjective emotional feeling. James-Lange theory is quite contrary to the normal way of thinking about how emotions arise, in which a person firstly perceive a stimulus which then gives rise to emotions that in turn trigger bodily responses. Therefore, James and Lange believed that a person must first have a bodily reaction and only afterwards is the emotion felt (Dalgleish, 2004; Gazzaniga et al., 2014).

**Cannon-Bard theory.** Contrary to James and Lange, the famous scientists Cannon and Bard proposed that the physiological varieties of experiences in response to a stimulus are not vast enough and are further too different in order to discern between fear, anger and sexual attraction, for instance. Therefore, the Cannon-Bard theory claims that following the perception of the emotional stimulus that reaches the thalamus, the stimulus is redirected towards both neocortex which enables the generation of the feeling and to the hypothalamus.
which is responsible for generating the physiological changes (LeDoux, 2002). The Cannon-Bard theory describes a model in which emotions are processed in parallel (Dalgleish, 2004; Gazzaniga et al., 2014). Back in 1928, Cannon and Bard performed a set of experiments on decorticated cats to try to find the brain areas responsible for emotion processing. They observed the so called “sham rage” phenomenon on decorticated cats leading them to disagree with the James-Lange theory that claims emotions are just perception of bodily changes. After being exposed to a light touch stimulus, decorticated cats became very angry and expressed an ill-directed behavior with physiological changes such as arching their backs and exposing their teeth. From this experiment it was shown that perception of emotions is not entirely dependent on intact cortices, and that the role of the cortex in this case is to top-down regulate the expression of uncontrolled emotions such as sham rage, which are processes in the hypothalamus (Dalgleish, 2004).

Figure 2. The model of parallel processing of emotions according to Cannon-Bard theory.

The Papez circuit. Papez proposed back in 1937 a neuroanatomical emotional system in which following stimulus perception, the thalamus further distributes the stimulus in two directions. One route is represented by an upstream “thought” system which involves a transmission from thalamus to the sensory cortex, more specifically the cingulate cortex, and is responsible for the conversion of stimuli into memories, thoughts and perceptions (Dalgleish, 2004). The second route also known as the “feeling stream” involves the transmission from thalamus to the mammillary body (part of hypothalamus) which enables
the generation of emotions. From here transmission can go further to the anterior thalamus and cingulate cortex. The top-down emotion regulation described in the Cannon-Bard theory is also present here, and is made of the transmission from cingulate cortex to hippocampus and then to hypothalamus (Dalgleish, 2004; Gazzaniga et al., 2014).

Figure 3. Papez’s circuit and neural networks that supports emotional stimuli processing. (adapted from Dalgleish, 2004).

**Kluver-Bucy syndrome.** Later on in 1939 Kluver and Bucy performed experiments in monkeys which had a bilateral anterior temporal lobotomy and observed a behavior pattern characterized by a decreased emotional reactivity, a tendency for exploring objects with the mouth, abnormal eating behavior and hypersexuality. Furthermore, these monkeys lost their fear for snakes. The Kluver-Bucy syndrome points to an important role for temporal lobe in emotion processing and is one of the findings that stand at the basis of MacLean’s limbic system model (MacLean, 1949).

**MacLean’s limbic system and emotions.** In MacLean’s original paper from 1949 the main idea transmitted was that in order for an emotional experience to occur, an integration step is needed. In this integration process messages from body responses to external stimuli are sent to the brain where they come together with perception of the outside world and this
therefore enables the occurrence of subjective emotional feelings (Dalgleish, 2004; MacLean, 1949).

**Figure 4.** MacLean’s model for emotion generation.

In his paper, MacLean refers to hypothalamus as ‘the head ganglion of the autonomic system’ (MacLean, 1949). Taking into consideration previous results from the experiments on decorticated cats performed by Bard back in 1928, the hypothalamus is proposed to be the brain region that facilitates the experience of emotion and its expression (MacLean, 1949). However, although MacLean ascertains the important role of hypothalamus, his paper indicates that the cerebral cortex is the brain structure that enables the distinction between various emotional states such as love, anger, hate, etc. (MacLean, 1949). Therefore, the role given to hypothalamus is that of “effector mechanisms of emotional expression” while the cerebral cortex facilitates emotional experience (MacLean, 1949).

**Evolutionary Theories of Emotion**

**Plutchik’s theory.** According to psychologist Robert Plutchik Human emotions have deep evolutionary roots, a fact that may explain their complexity and provide tools for clinical practice” (Plutchik, 2001). Following on Darwin’s ideas, Plutchik claims that emotions serve adaptive and survival roles in all animals, including humans, and are organized on the basis of intensity, similarity, polarity and grade (primary/fundamental or secondary/derived) (Plutchik, 1980). Plutchik defines emotions as “…a complex chain of loosely connected events that begin with a stimulus and include feelings, psychological changes, impulses to action and specific, goal-directed behavior” (table 1) (Plutchik, 1980, 2001).
Table 1. The sequence of events that lead to the development of emotions. A specific stimuli or event such as threat is followed by cognitive appraisal which can also happen unconsciously and has the role to label the situation as dangerous, in this case. This in turn leads to subjective feelings such as fear that triggers the appropriate behavior of escaping that has the aim to deal with survival problems (table constructed according to Plutchik, 2001).

<table>
<thead>
<tr>
<th>Stimulus event</th>
<th>Cognition</th>
<th>Feeling state</th>
<th>Overt behavior</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threat</td>
<td>‘Danger’</td>
<td>Fear</td>
<td>Escape</td>
<td>Safety</td>
</tr>
<tr>
<td>Obstacle</td>
<td>‘Enemy’</td>
<td>Anger</td>
<td>Attack</td>
<td>Destroy obstacle</td>
</tr>
<tr>
<td>Gain of valued object</td>
<td>‘Possess’</td>
<td>Joy</td>
<td>Retain or repeat</td>
<td>Gain resources</td>
</tr>
<tr>
<td>Loss of valued object</td>
<td>‘Abandonment’</td>
<td>Sadness</td>
<td>Cry</td>
<td>Reattach to lost object</td>
</tr>
<tr>
<td>Member of one’s group</td>
<td>‘Friend’</td>
<td>Acceptance</td>
<td>Groom</td>
<td>Mutual support</td>
</tr>
</tbody>
</table>

The emotional stimulus can be both external as in the case of environmental stimuli or internal as in the case of emotions triggered by dreams. In the well-known wheel of emotions, Plutchik describes 4 pairs of contrasting states as the basic emotions: joy versus sorrow, anger versus fear, acceptance versus disgust, and surprise versus expectancy. From these 8 basic emotions a mixture of two or three emotions results in primary dyads, which accounts for states such as love that is a combination of acceptance and joy according to Plutchik (2001). Although, there is no widely accepted table of basic emotions among the contemporary followers of Darwin, basic level emotion categories typically include fear, anger, sadness, joy, love, surprise, disgust and contempt (Cornelius, 2000; Plutchik, 2001).

Shaver’s Prototype Theory. Cognitive theories indicate that emotion components are in fact just parts of a bigger complex, in which repetitive exposure to objects or events lead to generic mental representations. Emotional knowledge is also organized in generic representations that are often called schemas, scripts, prototypes or stereotypes (Shaver, Schwartz, Kirson & O’Connor, 1987). A cross-cultural study performed in 1987 with
participants from Italy, China and United States suggested that the six fundamental emotions (love, joy, surprise, anger, sadness and fear) play evolutionary roles (Cornelius, 2000; Shaver et al., 1987). Although this study points towards a great degree of overlap in fundamental emotions between the three countries studied, there are some social psychologists such as Averill, who argue that emotions are culturally constructed, and hence differ from one country to another (Averill, 1982; Shaver et al., 1987).

**Constructivist Theory of Emotions**

The social constructivist concept is the youngest approach taken to explain emotions. According to this group of theories cognition gives rise to emotions, but in this cognitive appraisal step social factors such as language and culture are considered (Gazzaniga et al., 2014).

![Figure 5. Constructivist model considers social factors such as language and culture in the process of emotion generation.](image)

The social constructivist approach to emotions has its roots in the work of James Averill and Rom Harré that was published in 1980’s (Cornelius, 2000). Cornelius argues that according to Averill’ study of different societies can give us a glimpse of the whole picture of emotions and how are they formed. An example often used to show that emotions are social constructs is the emotion of “anger”. Normally, scientists that follow the ideas of Darwin and Ekman believe that emotions are hard-wired and claim that anger is a primitive emotion. On the other hand, social constructivists claim that anger is more than a primordial emotion; it actually plays a positive constructive role that rests on a moral judgment which allows us to
discern between what is right and what is wrong when it comes to social relationships, for instance. Therefore, social emotions such as anger modulate our behavior when it comes to putting boundaries between good and bad and to choose between what is appropriate or not in a social relationship (Cornelius, 2000). Social constructivists take into account culture and sex differences when describing the role of emotions (Cornelius, 2000). Culture is considered the major factor of content appraisal which gives rise to emotions, and in the case of “anger” it is said that people get angry differently in different circumstances (Cornelius, 2000).

In summary, over the course of time several theories arose trying to explain how emotions arise, what are emotions’ components in order to give a clear and concise definition. Although different theorist acknowledge some if not all the components presented above (the triggering stimulus, the physiological reaction, the appraisal, the subjective feeling and the behavioral response), they disagree on the order these components follow when an emotional experience occur. Moreover, more recent theories such as constructivists approach further take into account the language and culture as central elements on which emotions depend. In the next chapter of this study, the focus will be on the cognitive theories which have as central component the appraisal. This evaluation step will be described in detail according to the theories described below.

The Cognitive Approach to Emotions

The roots of the cognitive approach to emotions extend to the basic concept that an emotion is actually an evaluation named “appraisal”. Following this perspective, thought and emotion cannot be separated since emotions are dependent on this evaluation step. In this approach the cognitive evaluation is vital because it entitles us with the evaluation of an event, therefore judging the stimulus’ meaning and allowing us to take further action. An emotional experience consists of the cognitive appraisal component, neurophysiological processes, subjective feeling, facial expression and the new action (Moors et al., 2013; Oatley
Although appraisal is a popular term widely used in the study of emotions, not all scientists consider appraisal to be a component of the emotional episode. Given that perception requires more time to occur compared to an emotion and because emotions can also occur outside of stimuli awareness, LeDoux does not consider valid the cognitive approach (LeDoux, 1996). The reply of other cognitive scientist to this critique is that the appraisal process is not understood as it should be: direct, automatic, immediate and not deliberate. Appraisal is therefore automatically triggered by environmental stimuli and is responsible through its variety of combinations (pleasantness, certainty, effort, agency, coping potential, control) for the diversity of particular emotional responses to these stimuli (Cornelius, 2000). Among cognitive scientists emotions are approached from different angles according to the different theories they follow, but the most widely used and fast developing are Frijda’s action readiness theory, the communicative theory of emotions and Russell’s core affect theory (Frijda & Parrott, 2011; Oatley & Johnson-Laird, 2011; Russell, 2003). Stressing on these three most representative approaches, the aim of this section is to outline some of the existing cognitive theories, bringing out their similarities and differences.

**Appraisal theory**

This group of theories maintains that each person decides alone and considers differently the importance of a specific stimulus and therefore the emotional feeling might be different from one person to another. According to these theories, the cognitive interpretation (appraisal) of the stimulus, which can also be automatic and unconscious, is followed by the emotional feeling and hence the order of the emotional processing steps is quite different compared to the above described theories (Gazzaniga et al., 2014).
Figure 6. Appraisal theory of emotional stimulus processing and emotion generation.

The appraisal process evaluates and judges how significant certain concerns such as goals, needs, values and beliefs are for the individual’s wellbeing. The cognitive relevance in the emotion process stands on the ability to distinguish between different emotions by making use of certain variables. Such variables include goal relevance, congruity, certainty, agency, coping potential and control which are generally accepted as the core set of appraisal variables (Moors, Ellsworth, Scherer & Frijda, 2013). Additional appraisal variables (novelty, expectancy, urgency, fairness, compatibility) are set by different theorists. These variables can be defined according to their nature. A higher number of variables and the variable’s nature are the factors that dictate the variety of emotions that can be described (Moors et al., 2013). The difference between appraisal theories and other theories that have an appraisal component as part of a complex emotional process is the role given to appraisal, which in this case is fundamental. Therefore, not all theories that contain an appraisal component fall under this category, but only the ones that nominate this component as central. Appraisal component won its importance through the fact that is responsible for the initiation and differentiation of emotional episodes, and because appraisal dictates the quality and intensity of the other emotional components (action tendencies, physiological responses, behavior and subjective feelings) (Moors et al., 2013).

Schachter-Singer theory

According to this theory two factors make up the emotions. One factor is physical arousal and the second is our interpretation of the arousal, therefore this theory is also known as the ‘two factor theory’. Comparing this concept with the James-Lange theory of emotion
where emotions are basically the interpretation of the physiological response to stimuli, Schachter and Singer claim that our interpretation of the physiological response to the stimulus depends on how we see the situation (Schachter & Singer, 1962). This theory does follow a normal way of thinking since different emotions often share the same similar physical responses and experiments so far have not identified a clear physiological differentiation for the various affective states that a human being is able to experience. The inability to match every single emotional state to a visceral pattern, lead Schachter to suggest that the major factor that draws the line between different emotions is cognitive appraisal (Gazzaniga et al., 2014; Schachter & Singer, 1962). Hence, according to this concept, emotions are, as the authors wrote “a state of physiological arousal” with the cognition determining this state either as joy, anger or fear (Schachter & Singer, 1962).

Figure 7. Two factor theory of emotion as described by Schachter and Singer.

The emotion generation model proposed by Schachter and Singer had at the basis three propositions based on the interaction between cognitive appraisals and physiological arousal. Firstly the cognitive elements of a specific situation determine the emotional state and are therefore potent determinants of emotions. This then leads to the idea that cognitive manipulation can in turn change emotions (Schachter & Singer, 1962). Secondly, an already clear and appropriate explanation for a specific physiological arousal does not require a cognitive appraisal to label a feeling (e.g. “Adrenaline injection caused me the feeling”). In here, the terms “feeling” and “emotion” are interchangeably used. Finally, the third
proposition put forward claims that cognitive appraisal cannot be classified as an emotion if the physiological factor is absent (Schachter & Singer, 1962).

**Action-Readiness Theory**

Similar to Jamesian and Darwinian views, the Dutch psychologist Nico Frijda also regards emotions as predispositions to react to different circumstances and as emotional adaptations, from where he also took the name of “action tendencies”. Similar to other scientists Frijda believes that putting effort in defining the word “emotion” will lead us into endless discussion, and therefore he describes emotions as subjective experiences. To better understand the ‘action tendency’ term, basic emotions will serve as examples. For instance the basic emotion of joy, is defined as ‘…the sense of pleasure plus the urge towards exuberance and contact-seeking’ (Frijda, 1988). Action-readiness is defined as motive states or ur-emotions, which lie beneath the feeling of emotional need or action tendency which in turn leads us to engage in certain behaviors (Frijda & Parrott, 2011). Frijda considers that a particular kind of emotion arises in response to certain events that have meaning for the individual. An example of this is, say, grief which arises in response to losing someone close to us. Hence, the input event that affects us changes the degree of the emotional output (Frijda, 1988). In this theory, the meaning of the input event is responsible for giving rise to emotions, and not the event itself. Following up, the meaningful event is then judged according to relevance and concerns, a process termed relevance evaluation. Judging if the person is able to cope with the situation and what is the best course of action, constitute the appraisal step or context evaluation. The emotion intensity is determined during the process of urgency evaluation. All these evaluation steps form the basis of action tendency that can have three possible outcomes: emotional perception, behavioral expression (facial expression, verbal and non-verbal behavior) and physiological responses (accelerated heartbeat, arousal)
The action-tendency theory follows the cognitive view of emotion described by Jean-Paul Sartre argued that emotions have the role of helping us to understand the world.

The appraisal process in Frijda’s cognitive theory of emotion considers that the evaluation of the environmental stimuli is necessary to inform us about specific environmental characteristic and allows us to prepare the action readiness (Cornelius, 2000). Action readiness represents one of the components that make up the process of emotions which follows a complex and dynamic pattern made of several steps. The components of emotional process have the following roles: appraisal is the evaluation component, the motivational components determine the action readiness, physiological responses are part of the somatic component, behavioral changes and facial expression which are part of the motor system, and the subjective feeling.

Frijda introduced the term “ur-emotions” which are the non-emotional building blocks of emotions that have the aim to prepare us to take certain action in order to achieve particular goals. The notion of ur-emotion as building blocks is quite similar to the stimulus-response pair concept used to describe the componential theory (Clore & Ortony, 2013). Ur-emotions or states of readiness are driven by their motivational feature with the purpose to engage or disengage in order to achieve the desired goal (e.g. decreasing the danger is the aim of fear). The appraisal process which can happen automatically and unconsciously is defined by its variable of pleasantness and unpleasantness with the aim to prepare us to approach or avoid the appraised event/person/environment (Frijda & Parrott, 2011). Action readiness gains popularity and continues to stand at the basis of emotion explanation for three major reasons; is considered the base on which emotions function, it can be identified in infants and animals from their behavior and is considered consistent across cultures, under different situations and across species. Action-readiness states can be approached through analysis of expressive behavior, the co-occurrence of social behaviors, self-reports of emotions, questionnaires that
correlate items of action readiness and facial expression photograph rating analysis. Ur-emotions can be thought as mental states that upon activation can result in one of the several outcomes: they can produce actions, thoughts and physiological changes, remain states of readiness without further action or remain just urges but with no motor manifestations (Frijda & Parrott, 2011). But what trigger ur-emotions activation and subsequent pathway? Appraisal of events is one factor that can initiate and activate emotions, but also imagining, executing or viewing an action (e.g. dancing), a facial expression or a posture can activate the mental action readiness structures and lead to further motivational, motor and cognitive responses (Frijda & Parrott, 2011). I believe that the fact that the mental representations of action readiness can be activated by imagination or posture is a breaking ground for further studies on how to build up confidence and a kind of brain plasticity that nicely follow the quote “fake it until you make it”.

Describing feelings can also help unfolding ur-emotions. This is what Frijda wanted to say when he defined emotions in terms of subjective feelings (Frijda, 1988; Frijda & Parrott, 2011). While experiencing a subjective feeling we can be aware of the autonomic responses, we can be aware of the stimuli while its evaluation takes place but we can also feel just urges (Frijda & Parrott, 2011). To better understand the concept of ur-emotion, submission will serve as example. According to Frijda, submission is the ur-emotion that is encountered across many different emotions such as shame, amae, awe, admiration, humility and respect. And in each of these emotions, submission differs according to the appraisal that induced it. For instance, submission is recognized in the emotion of shame from the submissive posture of head being bent forward. In the emotion of awe, submission plays the role of recognizing the superiority and power of someone. In the process of humility, submission is characterized by identifying and accepting another’s power and prestige (Frijda & Parrott, 2011). Another case is the encounter of ur-emotion of helplessness in the
emotional responses of misery, pain, anxiety, panic, burnout, muslim syndrome and acedia. As in the case of submission, helplessness is present in all the above mentioned emotions, but the difference between these states is made by antecedents, circumstances and appraisals.

Frijda claims that action readiness has an elementary innate form, which plays basic survival roles and promotes processes of locomotion, adjusting sensory organs like antennae, extending limbs or tasting with tongue in animals. This rudimentary form has later on developed and become cognitive, allowing an anticipation of the upcoming events in the environment. Therefore, ur-emotions are actually considered innate. The neurochemical transmission of dopamine, oxytocin, vasopressin and serotonin further provide support for the innate existence of ur-emotions. Anxiety, pain reduction, antisocial behavior and parental behavior have been shown to be positively affected by oxytocin, data used to support the innate structure of ur-emotions.

To conclude, Frijda’s theory states that ur-emotions are the substrates of emotions to which the theorist refer as tendencies to react.

**Communicative Theory of Emotions**

The communicative theory of emotions was introduced by Oatley and Johnson-Laird who claim that the roots of emotions are based on social mammals and that emotions that are molded by natural selection have cognitive and functional roles (Nesse & Ellsworth, 2009; Oatley & Johnson-Laird, 2011). According to this theory, emotions enable individuals to use appropriate mental resources to different events, which further allow them to engage or disengage in possible relationships. The communicative theory is cognitive in the sense that it considers emotions cognitive as appraisals of the events that are important for our plans and goals (concerns according to Frijda’s theory).
We live in a world which functions according to a certain set of modes but in which the unpredictable takes place and interrupts our goals and plans. When goals and plans are interrupted, it is unlikely for us to come up with all the possible continuations and therefore, the theorists of the communicative approach claim that the role of emotions is revealed in such unexpected situations. Emotions have the functional role to update the cognitive system and prepare us for a small set of possible outcomes which might further occur. In such situations, fast appraisals are made. When a dangerous situation gives rise to fear, the plans and goals that we used to have are stopped and fast appraisal of situation and possible outcomes are considered before taking further action. In this way, the cognitive system is upgraded and prepares us for fight or flight actions. If the dangerous situations passes, one can retake the initial course of action, or otherwise follow an option from the small set of possibilities created. According to the communicative theory, as emotions occur we can be aware of the cause of the emotions. This is to say that we are conscious of the emotional stimuli, but we are unconscious/unaware of how the emotion itself comes to happen (Oatley & Johnson-Laird, 2011, 2014).

Under this approach, basic emotions are classified either as free-floating or without an object or with necessary objects, categories without propositional content. Basic emotions are termed by Damasio (1994) primary and are thought to lack propositional information because their formation relies on a rapid and direct pathway from the sensory thalamus to the amygdala and therefore the perceived information is crudely appraised (Damasio, 1994; Oatley & Johnson-Laird, 2011). Basic emotions that can occur without objects include happiness, sadness, anxiety or anger. This is to say that we can feel anxious without knowing the reason (we have no object) and we cannot say much about the feeling (it has no propositional content). Another example is the possibility to experience joy when one listens to a new piece of music- we cannot say much about the music since is new to us (no
propositional content). In contrast, other basic emotions need to have an object. Such emotions include parental love, sexual love, disgust and hatred. For instance, in the case of parental love, the necessary object is represented by the offspring (with necessary object). In case of disgust there is always a noxious entity towards which we feel the disgust (the presence of an object) (Oatley & Johnson-Laird, 2011).

According to the communicative theory, nine emotions are considered basic: happiness, sadness, anger/irritation and fear/anxiety are considered free floating, while attachment love, parental love, sexual love, hatred and disgusts are classified as emotions with necessary objects (Oatley & Johnson-Laird, 2011; Oatley & Johnson-Laird, 2014). The theory mentions four main features used to qualify an emotion as basic: it needs to have a psychological cause (such as maintaining life, sexual relation, avoiding danger and taking care of offsprings); it can have objects but no propositional content; each emotion has characteristic behavior, facial expression and bodily posture; and has no lower level states of existence since basic emotions are primitive (Oatley & Johnson-Laird, 2011). Other emotions are considered borderline because of their ambiguous nature: surprise (could be happy or sad), sexual jealousy (can be hatred or possessive love), shame (is associated with blushing but blushing is also associated with shyness), and guilt (no conclusive facial expression and it cannot be identified in other species) (Oatley & Johnson-Laird, 2011). Complex emotions such as jealousy, remorse, envy and pride contain at least one basic emotion (embarrassment, anger, fear, hatred) but the distinction resides on complex emotions being conscious, triggered by appraisal of the propositional content, and their great relevance for our wellbeing (Oatley & Johnson-Laird, 2014). Termed by Damasio (1994) secondary, complex emotion formation relies on a slower and longer brain pathway that involves the flow of perceptual information from the sensory thalamus to the ventromedial prefrontal cortex (where the propositional content is formed) and then to amygdala, which activity is also crucial for the
intensity of emotions as in the case of fear (Damasio, 1994; LaBar, Gatenby, Gore, LeDoux & Phelps, 1998; Oatley & Johnson-Laird, 2011). The existence of complex emotions depends on the propositional content implies the diversity of emotions created by cultures and societies (Nesse & Ellsworth, 2009).

Two features of emotional experiences, namely valence (pleasant/unpleasant) and intensity (activation/deactivation) are the two dimensions recognized by most of emotion theorists (Nesse & Ellsworth, 2009). But what defines emotions and their characteristics are a matter of evolution and situations that we face. This also explains the overlap between different emotions. Since we face situations that have similarities and overlaps, the emotions that might arise can likewise have overlapping features. Therefore, as argued by Nesse and Ellsworth (2009) emotions are shaped by evolution and not by the stimuli or brain modules.

In terms of the functions, communicative theory claims that one emotion serves more than one function, which can be regarded as advantageous in certain situations. Examples include disgust which triggers and promotes avoidance and vomiting, and lust which initiates seduction and sexual intercourse. If distinctions are to be made between negative and positive emotions, we can say that negative emotions motivate us to identify and avoid misfortune by taking certain actions such as escaping from a dangerous situation or attacking. The positive emotions promote flourishing, motivate engagement in actions that lead to success in goals and plans that are relevant for the organism (Nesse & Ellsworth, 2009).

**Core Affect Theory of Emotions**

Core affect, a state without introspective access triggered by level of arousal and pleasure vs displeasure and with influences on perception, cognition and behavior, is being said to be the cause of emotions according to the Oatley & Johnson-Laird (2014) and Russell (2003). In the generation of emotions, social construction impregnates its customs and cultural influences, giving rise to overlapping emotional prototypes such as fear and anger.
Similar to other theories, this theory assumes that an emotional experience consists of an emotional stimulus, its perception quality, an object as described in the communicative theory, appraisal of the object and the triggered behavior. Core affect theory regards emotions as overlapping prototypes that can share features of facial expression (Oatley & Johnson-Laird, 2014).

In his article published back in 2003, Russell claims that an emotional experience is constructed by a combination of various components that have at their base the two dimensional factors: valence (pleasure versus displeasure) and arousal (activated versus deactivated). The proposed framework stresses the central role and importance of emotions in life and everyday vocabulary, taking into account both the cultural and biological influences. This is not to say that an emotion is equivalent with core affect (Russell, 2009). The intensity (from mild to intense), rapidity (from slow to fast), extent of involvement, and duration (short-lived or long-lasting) of the core affect determines the emotional episode experienced. There are a variety of factors that can influence and manipulate core affect changes: genetic factors, internal causes (hormonal changes, immune cell activity), external causes (intense external causes that overcomes others), accumulated stress, drugs (stimulants, depressants, euphoriants), sensory registration and cognitive processing. People often seek to regulate their core affect in order to optimally cope with daily challenges. Examples include people that suffer from anxiety (unpleasant, high arousal state) and look for serenity (pleasant, low arousal state), stressed people that try to calm down or fatigued persons that seek to arouse and feel energized (Russell, 2003). Some of the roles of core affect are: cognitive processing guidance, influence of behavior (decision making or simple reflexes), implicated in preferences and attitudes, and influence motivation, reward and reinforcement. On the more specific roles, Russell mentions that a pleasant core affect facilitates attention toward positive material and positive evaluation of judgments. In this category, a feeling of enthusiasm
directs a person towards optimistic perspectives while preparing plans and goals. On the other hand, unpleasant cores affect redirects attention towards negative material. An example of this is the feeling of being depressed described as displeasure and low arousal which gives a person a sense of pessimism, redirecting behavior towards choosing less demanding tasks that require less hard work. High arousal states are characterized by facilitated accessibility to high arousal material, which is optimal for simple cognitive tasks. Low arousal states enable accessibility towards low arousal material, which seems to be best for complex cognitive tasks. The overlapping and highly influential components that form the prototype of a specific emotion include: core affect, affective quality (the capacity of a specific stimulus to change the core affect), attributed affect, previous events, appraisal, instrumental action, physiological and expressive changes, subjective conscious experience, emotional metaexperience and emotional regulation (Russell, 2003).

Although Russell was the first to introduce the core affect term in the study of emotional experiences, the concept is not new. Writers and psychologists previously described the same two dimensional perspective using terms such as pleasant-unpleasant, excitement-calm or tension-relaxation. These dimensions are universal and not only used when describing emotions. Sex behavior, aggression, drug abuse, eating pattern, self-esteem preservation, cognition and decision making, research on biology, and linguistics, all make use of the concept of valence when investigated. Herein, the two dimensions are considered states of central nervous system that are subjectively experienced and have physiological correlates (Russell, 2003). Evidence that ascertains the existence of the two dimensional core affect involves the analyzed data obtained from participants that performed a variety of tasks such as imagining a certain emotion triggered by an imaginary situation, reactions to sounds and photographs, describing current mood through self-reports and remembrance of emotional experiences.
Although evidence for valence and arousal as underlying patterns of core affect exists, critics call for the need of other dimensions to fully explain such a broad and complex state as an emotion (Russell, 2003). Valence is said to incorporate states other than emotions (tiredness and sleepiness), and valence and arousal do not differentiate between anger and fear, embarrassment and guilt, jealousy and disgust. Further criticism involves the extensive use of linguistic terms, synonyms for valence (positive-negative, hedonic, utility, approach-avoidance) in research literature that do not resemble Russell’s concept of the pleasure-displeasure dimension. Likewise, linguistic problems are raised as obstacles while describing and investigating emotions (Russell, 2009). Common sense tell us and we must recognize the crucial role words play in our everyday life and in the scientific world of emotions, without a vocabulary we could not speak or write (Russell, 2009). As a response to this critique, one must take into account that even if categorization of emotions is ruled out (emotions categorized as anger, fear, envy, content, frustrated etc.), its components still remain. For instance, we might stop calling it anger but the manifestations of the emotion would still be there: the tense microexpression, the increased heart rate, urges to act with an aggressive behavior (Russell, 2009). Some other criticisms include the inconsistency of corresponding peripheral autonomic activity measured as skin conductance, heart rate, blood pressure with the arousal dimension which according to Russell is a mental state with a subjective feeling and physiological correlate components (Russell, 2003).

The core affect theory is not fully developed and further work is needed to shape and improve the understanding of emotions through this perspective. As a response to the herein mentioned criticism, the two dimensions described are not the only ones needed or sufficient, but are indeed widely recognized as the fundamental ones used in the description of emotional experiences (Kuppens, Tuerlinckx, Russell & Barrett, 2013). Core affect as described above is thus just a critical component found under the psychological construction
of emotion (Russell, 2009). Core affect can be found at different points in our consciousness, ranging from focal to out of sight. The important point here is that there is a need among scientists to distinguish between core affect and emotions at the level of their concept and their features.

Core affect is not alone sufficient to explain emotions, for this reason an umbrella term has been introduced, which account for core affect as one of the important continuous components of emotional experience. Psychological construction sustain that the issue in investigation emotions is that we search and suppose that a single mechanisms or process is responsible for the whole variety of emotional episode (Karnaze, 2013; Russell, 2009). According to psychological construction emotions cannot be defined by one single theory, since all the theories mentioned so far are not able to fully explain all the mechanisms, origins and consequences of all emotional states (Russell, 2009). Emotions are formed differently and in accordance with the different situations that each person is facing (Russell, 2009). The way to succeed in unravelling emotions is to unite knowledge from different theories, and work on understanding the different components of an emotional episode and the correlation among these components. It is crucial to understand that through an individual’s life the different components that make up emotions (facial and vocal expressions, autonomic nervous system responses, appraisal, emotional behavior, the experience of having an emotion, attribution and emotion regulation) are constantly depending on situations (objects and events) that we face (Russell, 2009). Each combination of these components (not necessarily all at any single time) give rise to a different emotion (anger, fear, sadness) but in the same time can result also in a non-emotional episode (Russell, 2009). On this account we must consider that there are certain components that are always present: core affect, behavior, appraisal, perceiving and autonomic nervous system (Russell, 2009). To conclude this theory, only a thorough investigation and explanation of
components, of emotional episode and their patterning will enable a successful advance in the
science of emotions (Russell, 2009).

In summary, the core affect theory argues that valence and arousal are the two main
components of core affect, but not the only ones required for an emotional episode to occur.

**Similarities and Differences between the Action-Readiness, Communicative and Core
Affect Cognitive Theories**

Although the three cognitive theories presented here are the ones that developed the
most, other cognitive theories of emotion exists. A closer look into the features of these three
emotion theories unravels both similarities and differences.

A similarity on which all three theories converge, concerns the number of
methodologies used to measure and categorize emotions. Measure of only one component of
emotional experience such as physiological response, behavior or experiential emotion is
neither sufficient nor indicative of an emotion (Oatley & Johnson-Laird, 2014). All three
theories agree on the fact that the appraisal process of the events that concern us is the cause
of our emotions. Without appraisal, no emotion is to occur. A more detailed observation
regarding the appraisal process on which all three theories concur is that appraisal consists of
three phases: an initial phase which occurs outside our consciousness, a secondary appraisal
that involves consciousness and reflects on what the emotion is and prepare us for further
action, and the last phase which is a social appraisal (Oatley & Johnson-Laird, 2014). On the
importance of plans and goals, both the communicative and Frijda’s action readiness theory
agree that these are central to emotions and are important for driving the direction of our
future actions.

Regarding differences among the three theories three main issues can be pointed out
(Oatley & Johnson-Laird, 2014). The outcome of the first appraisal phase is distinct in all
three theories. Action readiness theory claims the unconscious appraisal result in a state of readiness. Communicative theory ascertains that the initial appraisal outcome is a small set of basic emotions and the core affect theory claims a state of pleasure or displeasure (valence) is the result of the unconscious appraisal (Oatley & Johnson-Laird, 2014). Even if Frijda’s theory and Russell’s theory consider emotions appraised as negative or positive, the communicative theory argues that a set of basic emotions is the result of the appraisal process (Oatley & Johnson-Laird, 2014).

In my opinion, since dissimilarities and similarities are observed between these theories, and since no single theory is able to fully describe emotions with its causes, manifestations and consequences, as Russell stated (2009) I agree that the differences observed point out towards a need for different theorists to work together. I think that even if some of the theories seem reasonable and convincing in their explanations, the inability to explain different emotions (basic or complex) through the same theoretic features means that either the theory is not complex enough and bits and pieces are missing or that emotional experiences are so different that no single approach can account for all these states.

**Neural Correlates and Measurements of Emotions**

**Neural Correlates of Emotions**

The subjective feeling component of emotions makes these psychological states very difficult to be objectively studied. Given that a person can experience more than one emotion at a single point in time, makes emotions so complex and confusing even for the person that is experiencing these states. Hence, the empirical studies often encounter challenges that need to be overcome (Plutchik, 2001). The complexity, diversity and variety of mixed emotions that one can experience do not match the language lexicon available in order for a person to describe accurately what he or she feels. Therefore, it can be difficult for scientists to obtain accurate objective data from participants in the study of emotions. When deciding to
objectively study emotions we might also take into consideration that emotional experiences can also happen unconsciously, can be suppressed or inhibited, and as psychoanalysts believe, these states are not always available to introspection. On the other hand, contemporary behaviorists consider that the closest we can get to emotions is by observing peoples’ behavior while classical behaviorists thought that emotions do not pertain to science to be studied (Plutchik, 2001). One thing that is for sure is that we live in a world in which every single decision that we take influence further our behavior, the way we feel, think and act. The choices we make regarding our career, deciding to take our relationship to the next level and found a family, people we chose to interact with and form friendships, or moving country are just a few examples from an infinite number of situations that take into account the emotional factor, and further shapes how we feel. Playing such significant role in biasing our decision-making process and directing our behavior, these psychological processes are centered in our lives, greatly influencing our wellbeing. Therefore, it is crucial to understand how emotions influence us in order to learn to modify them, redirecting our lives for better outcomes. In the objective study of emotions not only that we need to understand and learn where from our emotions arise, but is also crucial to get insight into the mediating mechanism that supports emotions and each of its components.

Affective neuroscience is the scientific field which works on identifying the neural mechanism that underlies emotional states (Davidson, Pizzagalli & Nitschke, 2009). In addition, a major field of study is the self-regulation, the study of how we control our emotions but also how our emotions control us. Emotions are approached by scientists that study its antecedents, some are interested on how emotions are expressed and how we respond to an emotional situation, and others dedicate their research to identify the underlying emotion lexicon. The continuous development of language and language differences created by evolution, together with differences between individuals and cultures
leads to confusion and difficulties when scientifically approaching emotions (Scherer, 2005). Apart from all these scientific discrepancies, it is also important to understand the difference between feelings and emotions. Integrating cognitive appraisal, motivational and somatic response, feelings do not equal emotions, but are responsible for underlying the subjective experience of an emotion (LeDoux, 2015; Scherer, 2005). Features of emotions such as its rapidity to change, its behavioral impact, its intensity and duration must be taken into account when emotions are researched and categorized. For instance, the appraisal process is quite rapid, changing as we continuously assess the external factors (objects, events, persons) implying that the emotions are also constantly changed and readjusted making them non-static. Emotions are responsible for preparing our action tendencies towards goal oriented behaviors in some cases or disrupting an ongoing behavior in others. Its high intensity and short duration are features that allow scientists to distinguish between emotions, moods and other affective phenomena (e.g. preferences, attitudes, affect dispositions, interpersonal stances) (Scherer, 2005). In addition to distinguishing between emotions and other affective processes, emotional features further allows us to draw the line between utilitarian (enable us to adapt to significant events that influence our wellbeing- joy, fear, anger, sadness, guilt, shame, disgust) and aesthetic emotions (have no importance for our wellbeing- being full or wonder, bliss, fascination, harmony) (Scherer, 2005).

Another impediment when studying emotions is represented by the failure of scientists to provide a widely accepted framework for the number of existent emotions. Some scientists created a basic emotion category where we can find most of the utilitarian emotions mentioned above, but even among these scientists different ideas exist regarding the number of basic emotions. Moreover, other researchers like Scherer which prefers to call the basic emotions modal, further add to the number of disagreements on nomenclature when it comes to categorizing emotions.
Despite all the above described obstacles, the study of emotions is advancing alongside its measurements. Scherer submitted that the design feature approach is suited for the study of the folk concept of emotion because it allows identification of existing emotions and differentiation between them, taking into account the language evolution history and ongoing development. It is also worth noticing that given that an emotion is described as a set of components of an organized whole, the measuring approach should also assess all changes in these individual components; therefore a convergent approach should be employed (Shaver, Schwartz, Kirson & O'Connor, 1987; Russell, 2009). The components of an emotional process that should be continuously assessed are: (1) the continuous changes in the appraisal process, (2) the neuroendocrine, automatic and somatic responses, (3) the motivational changes, (4) facial expression, vocal changes and body postures, and (5) the subjective experience (the feelings) (Scherer, 2005). Although such a single complex assessment procedure for emotions does not exist at the moment, scientist approached emotions from different angles: measuring appraisal, brain mechanisms involved in emotion process, measuring peripheral physiological changes that accompany emotions and expressive behavior observations. While the physiological changes and the monitoring of facial expressions and body postures gives us objective information about the emotional state of a person, the subjective approach of emotions is based only on individual reports, interviews and questionnaires. A problem in using self-reports is that they consist of ‘suggested’ answers and can confuse the participants and influence them therefore obtaining false data. In order to evade such errors sometimes free-response format questionnaires that take into account vocabulary and synonyms for emotional states are given to participants. Such test is the Geneva Affect Label Coder (GALC), which is actually an Excel program with the ability to recognize 36 affective categories with respective subcategories based on close synonyms and compatible between French, English and German languages. But even in
this case the downside of using such method is that it excludes the possibility for quantitative analysis (Scherer, 2005).

For this reason another approach for the analysis of subjective feelings is made through the use of The Geneva Emotion Wheel which is a forced choice response measurement. Two important tests in this category are the discrete emotional approach that is based on language differences that make a distinction between emotional states, and the dimensional approach that uses the valence (positive-negative), arousal (calm-excited) and tension (tense-relaxed) to get close to introspection (figure 8).

Figure 8. Geneva Emotion Wheel (adapted from Scherer, 2005).
While many approaches are taken to analyze the subjective feelings, none of the methods have been qualified as the right one. For this reason psychologists and researchers chose a method over another based on the theory they want to analyze.

In the cognitive approach, the most important dimensions taken into consideration when investigation emotions are valence (pleasant-unpleasant/approach-withdrawal) and arousal (activated-deactivated). We tend to weight emotionally charged objects and events as positive or negative, pleasant or unpleasant, approachable or avoidable (Davidson, 2003; Russell, 2009).

Investigating neural substrates of emotions is a major field of study in addition to assessing behavioral changes in response to events that are of major concern for an individual, evaluating the peripheral physiological correlates and assessing the subjective feeling through self-reports.

Limits to the study of emotions in humans such as ethical issues and technical restrictions, and controversy in the study of emotions and other conscious experiences in animals are considered boundaries that we need to overcome if we are to learn about these mental states that affect our wellbeing (LeDoux, 2015). Therefore, looking for the brain mechanism that underlies emotions depend widely on animal.

When looking for correlates of emotions within the brain, the electrical activity of neuronal cells is highly significant. One of the most used techniques to assess the brain activity in humans is the use of electroencephalography (EEG) which measures brain’s electrical activity through electrodes placed on the scalp. Although this technique brought significant knowledge and understanding in the field of cognitive neuroscience, the scalp represents an obstacle and distorts the neuron’s real electrical activity resulting in non-representative data. Limitation of the techniques such as spatial resolution can sometimes
slow down the process of advancing our understanding. Functional magnetic resonance imaging coupled with visual stimuli is also used in order to assess cognitive functions such as processing of emotions. Again, since no technique is 100% perfect, limitations such as temporal resolution also represent an impediment in obtaining clean and accurate results. Given that fMRI is actually assessing changes in blood oxygenation levels for instance in response to certain emotionally charged images and not directly the neuron’s activity, raises doubts concerning the exact brain area activated that correlates with in question emotional experience (Senior, Russell & Gazzaniga, 2006).

Intracranial electroencephalograph (iEEG) is another technique that combines the fine temporal resolution of electrophysiological techniques with in detail spatial resolution. Due to ethical reasons, in humans this measure is limited to patients subjected to brain surgery because of other health issues, therefore offering researchers a window for electrophysiological recordings while assessing neural correlates of emotions (Peron & Grandjean, 2014). This invasive technique measures in situ electrical activity either from single neurons therefore recording multi-unit action potentials or from small neuronal networks when it records focal field potentials (Peron & Grandjean, 2014). The electrodes of the iEEG can be placed either on the surface of the neuronal tissue or can take the form of implants deep within the brain tissue. There are a number of cases when implants are required. Deep brain stimulation is used to control the uncoordinated and unwanted body movements and dampen symptomatology in the case of Parkinson’s disease (PD), to alleviate the negative affective state in the case of emotional disorders such as depression or to enhance the cognitive functions in case of memory impairments (Peron & Grandjean, 2014).

The core dimensions considered to serve as the base from which to start investigating emotions are approach-withdrawal (pleasant-unpleasant) which pointed towards two
important brain regions tightly correlated with emotional experiences (Davidson, 2003). Presented below are neuroimaging studies based on arousal and valence features of emotional stimuli performed by distinct research groups. Amygdala and prefrontal cortex (PFC) are the brain regions generally accepted by most of the scientists that study emotions as having a role in these psychological processes (Anders et al., 2008; Blair, Morris, Frith, Perrett & Dolan, 1999; Davidson, 2003; Kensinger & Schacter, 2006; Nauta, 1971; Yang et al., 2002).

To summarize, the study of emotions is still classified as difficult if we try to study these states introspectively. An option when investigating emotions is the use of questionnaires. In addition, EEG, iEEG, fMRI, and PET are the available techniques used in animal and human studies to unravel the neural mechanisms that support different emotional states. Through the use of the above mentioned methodologies, scientists have found that amygdala and several cortical regions are correlated with distinct emotional states.

The following part of this report has the aim to provide evidence based on previous neuroimaging studies for the implication of amygdala and the PFC in the generation of emotional states.

**Amygdala**

**Amygdala and emotional experiences.** Amygdala is one of the brain structures generally accepted among scientists to play an important role in emotion processing (especially fear but not only) (Davidson, 2003; LeDoux, 2003; Wendling et al., 2015). Situated in the medial temporal lobe, amygdala has been mostly, but not exclusively, associated with fear (Fossati, 2012; LeDoux, 2007). Negative emotions like fear are among the most studied ones because the mechanism of such emotion is responsible for rapidly detecting and responding to life threatening stimuli. Based on a human male PET neuroimaging study, the negative emotion of sadness has been found to be correlated with amygdala activity (Blair et al., 1999). Blair and co-workers performed a PET study in which
they looked for brain regions that activate in response to three seconds presentation of grayscale face expression images on a screen. Images resembled different degrees of intensity of sadness and anger (Blair et al., 1999). Participants were told their task is to differentiate between male and females faces, while remaining unaware of the importance of the emotional variable. Contrast analysis between neutral and different intensities of sad and angry stimuli revealed a correlation between the activation degree in amygdala and the intensity of the sad stimuli (Blair et al., 1999). Other brain areas with increased activation to the different levels of sadness were the right, inferior and middle temporal gyri, and anterior cingulate cortex (ACC). With respect to the angry face expressions, the right orbitofrontal cortex (OFC) and bilateral anterior cingulate cortex were highly activated, while no significant changes in amygdala activation levels were identified between the neutral and different levels of perceived anger stimuli (Blair et al., 1999). This study was the first one showing that on top of responding to fear, the amygdala is also activated in response to sad but not angry face expressions (Blair et al., 1999). These results were further supported by an fMRI study which proved the activation of male and female amygdala in the processing of sad facial expression stimuli (Yang et al., 2002). In contrast, an fMRI study on adult male participants failed to detect the activation of amygdala in response to sad facial expression stimuli, but was in agreement with the activation of amygdala in response to both fearful facial expressions and fearful sounds (Phillips et al., 1998). Specifically, it was found that left amygdala was activated while perceiving black-and-white fearful facial expression while the right amygdala was activated in response to presentation of fearful sounds (Phillips et al., 1998).

As reported by a meta-analysis study based on previous neuroimaging data, the activation of amygdala has been associated not only with negative, but also to positive stimuli (Sergerie, Chochoł & Armony, 2008). Based on previous neuroimaging experiments it is
claimed that amygdala is activated in response to all kind of relevant visual emotionally charged stimuli (negative and positive), although a preference was observed in response to emotional face expressions (Sander, Grafman & Zalla, 2003; Sergerie et al., 2008). Evidence for hyperactivation of amygdala in the processing of positive stimuli comes from different fMRI studies in human adults and adolescents (Anders, Eippert, Weiskopf & Veit, 2008; Kensinger & Schacter, 2006; Yang et. al., 2002; Yang, Menon, Reid, Gotlib & Reiss, 2003). Based on their fMRI study in which seventeen adult individuals participated, Yang and co-workers (2002) reported that the amygdala was significantly activated for the four types of facial expression pictures used which resembled the emotions of happiness, fear, anger and sadness, compared to neutral faces. Based on statistical analysis, region of interest (ROI) studies and percentage of voxel activated, it was demonstrated that the amygdala activation level was not significantly different between the four emotional expressions. Furthermore, the authors also found no significant changes in the activation level between left and right amygdala for the four affect conditions (Yang et al., 2002). Concerning the fearful facial expression, it was observed that participants scored less on the accuracy in a gender discrimination task, results explained by the authors as a higher level of attentional involvement in the processing of fear compared to sadness, anger and happiness (Yang et. al., 2002). A more recent fMRI experiment is also stressing amygdala’s role in both positive and negative emotion processing (Kensinger & Schacter, 2006). In their human adult fMRI study eleven male and ten women participants (age 18 to 35) were scanned while seeing high-arousal negative, positive and neutral words and pictures. After an interval of 2.5 seconds for stimulus presentation, participants were instructed to respond either with ‘yes’ or ‘no’ when asked if the presented stimulus was animate or common, after which a 6-16 sec interstimulus interval was provided. Concerning the role of amygdala, the recorded data showed an increased activity in response to both high arousal positive and negative words and pictures.
compared to the neutral stimuli (Kensinger & Schacter, 2006). Furthermore, lateralization analysis studies point toward higher level of felt amygdala activation when processing high arousal words (either negative or positive) than when processing high arousal (either positive or negative) images. Bilateral amygdala was equally activated in response to high arousal pictures (either positive or negative) (Kensinger & Schacter, 2006).

Anders and co-workers performed and fMRI study in forty adult women (mean age 27) in order to investigate amygdala’s activity in response to visual and auditory stimuli. Furthermore, amygdala’s activity was explored in relation to two important features of emotional stimuli, valence and arousal (Anders et al., 2008). Their study provides strong evidence for the involvement of amygdala while processing both negative and positive stimuli (Anders et al., 2008). Valence was found to be more strongly correlated with the amygdala’s activity, compared to arousal. Lateralization analyses indicate a highly activated left amygdala in response to negatively valenced images, while the right amygdala was found to be more active in response to positively valenced images (Anders et al., 2008). A whole-brain analysis showed that negative and positive stimuli activate the right caudolateral orbitofrontal cortex, while the left region of the orbitofrontal cortex was activated only in response to negative stimuli. While the valence of a stimulus has a stronger impact on amygdala, the arousal of a visuo-auditory emotional stimulus is tightly associated with the right inferior orbitofrontal gyrus and the supplementary motor area from the dorsomedial prefrontal cortex (Anders et al., 2008). In the meta-analysis study performed by Costafreda and colleagues amygdala activity has been found to be closely linked to the arousal factor of the positive emotional stimuli. Their study suggests that given humor and happiness have the same valence, the fact that amygdala is more activated in response to humor lead to the conclusion that arousal is the component that drives amygdala activity in this case (Costafreda, Brammer, David & Fu, 2008).
In conclusion, based on imaging experiments from distinct laboratories the amygdala has been found to mediate several different emotions based on their valence and arousal. These emotions include both positive ones such as humor and happiness and negative ones such as fear, sadness and anger.

**Amygdala and the emotion of fear.** From the above described experiments it can be observed a clear correlation between amygdala and several emotional experiences. In this section the correlation between amygdala and the basic emotion of fear will be further discussed in detail. Results from experiments performed both in animals and humans will be described in order to expose the crucial role amygdala is playing in fear acquisition and expression.

In primates the amygdala (plural form- amygdalae) consists of 13 nuclei and was first associated with fear processing and internal representation of external threatening stimuli. The amygdala nuclei are divided in three main groups: the basolateral nuclear complex that contains the basal, lateral and accessory nuclei, the centromedial complex consisting of central and medial nuclei, and the cortical nucleus complex that is also recognized as the olfactory region of the amygdala (Gazzaniga, 2014; LeDoux, 1998). Amygdalar lesions point towards a loss of fear (in monkeys) as observed in Kluver-Bucy syndrome, the loss of distrust and caution, and a difficulty in learning to avoid dangerous situations (in humans).

When studying the neural correlates of fear, scientists use different approaches. Pavlovian fear conditioning is one procedure consistently used to study fear and to get insight into the mechanism through which amygdala is processing dangerous stimuli. This method consists in repeatedly pairing a neutral stimulus known as the conditioned stimulus (CS) which can take the form of a tone or light, with an aversive unconditioned stimulus that can be an electrical shock delivered to the feet. The final result following trials of repetitive pairing is a fearful response (CR-conditioned response) in the presence of the conditioned
stimulus (CS) but in the absence of the unconditioned one (US) (LeDoux, 2015). This paradigm closely resembles the real life threatening situation of encountering for instance a predator (LeDoux, 2003, 2007).

Based on this approach and on other previous studies, scientists gathered significant amount of knowledge on how different brain regions correlate or mediate certain emotions such as fear. Using this task in animal studies, details on neural circuits, cells and synapses have been revealed. Having the great advantage of being used across species, the same brain mechanisms that underlie the emotion of fear in animals (e.g. rats) (Brydges et al., 2013) have been confirmed to some extent to exist in humans (LeDoux, 1998, 2015). The aim of this section is to give an up to date insight on the role of amygdala in processing threatening/fearful stimuli by making use of relevant scientific work.

A closer look at the cellular and molecular level reveals the presence of various types of receptors on the surface of neuronal cells that make up the amygdala nuclei. Molecular and cellular changes that occur in the brain and enables emotions, rely on animal studies due to technical limits which scientists are still working on to overcome (LeDoux, 2015). The presence of receptors for a variety of neurotransmitters (glutamate, dopamine, acetylcholine, norepinephrine, and serotonin), peptides (neuropeptide Y, vasopressin, opioids, and oxytocin) and hormones (glucocorticoids, estrogen) suggest high input-output connections between amygdala and other brain regions (Gazzaniga et al., 2014). This further suggests that amygdala is correlated with, not only processing of fear but other emotional experiences as well (Gazzaniga et al., 2014). It is said that amygdala is involved in attention, perception, value representation and decision making (Gazzaniga et al., 2014). Amygdala output to the cortex infers its important effects in the arousal of the cortex and calling for vigilance in the face of ambiguous, novel and possible negatively valenced external stimuli (Davidson, 2003).
The roles of amygdala in emotional experiences have been revealed by the structural and functional changes related to symptoms of emotional disorders such as major depressive disorder (MDD), bipolar depression, and anxiety disorders (Davidson, 2003). In regards to structural changes, an increased in the size of amygdala have been found in depressed patients, depressed patients with bipolar disorders and temporal lobe epilepsy (TLE). Patients with MDD exhibit smaller right amygdala compared to right left amygdala, while and increased volume in left amygdala has been positively correlated with increased depression severity in TLE patients that also had symptoms of dysthymia (Davidson, 2003).

Concerning functional changes, depressed patients with MDD have been revealed to have increased resting regional cerebral blood flow (rCBF) and increased glucose metabolism for amygdala. In bipolar depression and anxiety disorders, amygdala has been found to be abnormally activated. Moreover, an increased density of 5-HT2 (5-hydroxytryptamine2) receptors that mediates excitatory neurotransmission in response to serotonin has been found on surface of amygdala neurons in depressive patients that committed suicide (Davidson, 2003). Pharmacologically treated depression have been reported to be correlated with a reduction in amygdala activity further supporting the crucial role of this brain regions in supporting certain affective states and moods.

It is widely mentioned in the scientific literature that emotions play an important role in cognitive processes such as perception, attention and learning. We can identify how emotions impact cognitive processes by being aware of our everyday life situations. For instance, we have all noticed that when we are sad we are unable to make decisions. Another example is when we enjoy an activity therefore we feel enthusiastic, we have the feeling the time is passing very fast and we might not even notice that we are hungry or tired (Gazzaniga et al., 2014). Thus, it is quite clear that emotional experiences play a crucial role modeling our cognitive processes and ultimately our behavior.
One well known example of how emotions impact the cognitive process of learning is summarized by Gazzaniga and co-authors. The psychologist Edouard Claparede had a patient that suffered from Korsakoff’s syndrome, a disease in which the individual is unable to form short-term memories therefore, every single morning the doctor introduced himself to the patient. Claparede performed the classical fear-conditioning paradigm on his patient by fear conditioning the CS (hand shaking) with the aversive US (a pin on his hand that eventually will prick the patient when they shake hands). Performing this experiment over several trials, Claparede observed that the patient was still unable to recognize him as her doctor, but hesitated when was about to shake hands. Therefore, the patient learned through experience (via implicit learning) to associate the handshake with the aversive stimulus (the pin). Through fear-conditioning paradigm this was the first time when implicit and explicit learning have been shown to occur via two different brain pathways: the low road and the high road. This means that the information about the aversive stimulus reaches the amygdala through low and high road. The low road known as the most rapid one, proved in rats to be 15ms, is the pathway through which the crude information is sent from thalamus directly to the amygdala without being consciously controlled. This pathway is crucial when we face dangerous situation because it prepares us for the fight or flight response (Gazzaniga et al., 2014; LeDoux, 2015). The second pathway or the high road is a little bit longer, consisting of approximately 300ms in rats. Through this pathway the information from the sensory cortex travels to the thalamus which sends it back to the cortex for a more detailed analysis. After this detailed analysis process, the information is sent from the sensory cortex to the amygdala (Gazzaiga et al., 2014; LeDoux, 2015). As with the fast low road which importance is crucial when encountering a bear for instance, the slower detailed high road is equally important because it allows us to receive accurate information in order to be sure that the dangerous stimulus is a fearful bear and not something else (Gazzaiga et al., 2014; LeDoux, 2015).
Based on PET studies on new born babies it was proved that the right amygdala preferentially responds to biological motion and that this ability is innate (Simion, Regolin & Bulf, 2008). Another study of single cell recordings from amygdala, hippocampus and entorhinal cortex also emphasized that the right amygdala preferentially activates in response to pictures of animals over pictures of objects or persons (Mormann et al., 2011).

Going back to fear conditioning, implicit learning is one way through which amygdala learns to respond to dangerous stimuli. As in the case of Claparede’s patient, although she had problems forming short-term memories, the patient successfully acquired CR via implicit learning (learning through experiencing aversive stimulus) as evidenced by her hesitation in shaking hands and her explicit report that she knew the handshake will hurt.

Early PET studies in human participants in which the classical fear conditioning paradigm was implemented, unraveled the importance of amygdala activity in processing of fear (Esteves, Parra, Dimberg & Ohman, 1994; Morris, Friston & Dolan, 1997). The post-hoc analysis of human PET studies performed by Morris and colleagues where emotionally charged facial expressions (CS) were paired with a burst of white noise (US) revealed several brain regions activity (Morris et al., 1997). More importantly, the right amygdala together with basal forebrain and bilateral fusiform gyri were activated, results that pointed to the importance of amygdala in acquiring the relationship between CS and the US (Morris et al., 1997). In addition, work from Esteves and colleagues extended the importance of amygdala in response to both consciously and unaware face stimuli, as demonstrated from the backward masking technique used (Esteves et al., 1994). From this study, the authors claimed that right amygdala is important in the case of CS presented outside of awareness, while the left amygdala was more activated when the CS was presented consciously (Esteves et al., 1994). Further neuroimaging studies using PET and fMRI scanning further supports amygdala involvement in responding to subliminal fearful stimuli (Morris, Ohman & Dolan, 1999;
Williams et al., 2006). Regarding fearful stimuli detection presented at the edge of conscious perception, the amygdala was also found as a neural correlate in an attentional blink task (Schwabe et al., 2011).

Damage to amygdala on the other hand, results in participants being able to respond to US alone (the pin in the hand) but fails to pair the neutral CS (the handshake) with the pin shirk (US) and therefore are unable to acquire the CR. Such is the case of the S.P. patient which suffered from bilateral amygdala damage (Anderson and Phelps, 2001). In a fear conditioning experiment S.P. has been presented with a blue square (neutral CS) for approximately 10s at the end of which a shock to her wrist was delivered (aversive US). Skin conductance was measured which revealed that S. P. exhibited a normal skin conductance response to US alone but even after a few trials, the patients failed to associate the blue square with the following mild shock. What was also revealed in this experiment was the fact that even if S. P. failed to acquire CR she consciously and explicitly reported that she knew that after the blue square the shock will come. The same fear conditioning experiment was performed with patients that suffered from bilateral hippocampal damage but intact amygdala. These patients were able to acquire CR, as measured by changes in skin conductance in presence of CS (blue square) alone after a few trials of pairing between CS and US, but when asked to explicitly report the pairing, participants inclusively denied seeing the blue square. Comparing results from these experiments, amygdala has been associated with the acquisition and expression of an implicitly conditioned fear response while the hippocampus has been shown to be crucial for acquisition of explicit knowledge about the emotional features of a stimulus (Anderson & Phelps, 2001; Gazzaniga et al, 2014).

From the above described experiments and resulting data, it is clear the important role the amygdala is playing in the implicit learning of fearful stimuli. Does amygdala also play a role in explicit emotional learning? Gazzaniga and co-authors used Liz’s situation to explain
what explicit learning means. As oppose to implicit learning where a person learns about the aversive properties of a stimulus by experiencing the stimulus (a dog’s bite which will lead to acquisition of fear in response to only seeing the dog), explicit learning lacks the fearful experience. In this case, the acquired fear Liz is experiencing, relies only on explicit information from others about the aversive properties of the dog. In order to explicitly learn about the aversive properties of a dog from others, an intact hippocampal memory system is required. So given the importance of hippocampus in explicit learning, what is the role of amygdala in this process? To shed light on amygdala’s role on explicit learning, the instructed fear paradigm was used in two groups of participants: participants with amygdala damage and control normal participants (Phelps et al., 2001). In this experiment, participants were instructed that after the presentation of the blue square (CS), a mild shock will follow (US). In reality, no mild shock was given to any of the participants. Given that participants with damaged amygdala had intact hippocampus, they successfully learned and explicitly reported that the appearance of the blue square will be paired with the mild shock. But when the blue square was presented alone, after the trials of supposed (fake) pairing of CS and US, the amygdala damage patients did not experience any emotional arousal response (no changes in skin conductance). In contrast, skin conductance changes (that indicates arousal) correlated with amygdala activity has been recorded in control participants (Phelps et al., 2001). The instructed fear task points toward the involvement of amygdala in the expression of fear when learning occurs explicitly. This form of explicit learning which is indirectly correlated with amygdala activation has a great impact in our lives, for instance when we need to teach our children to avoid threatening and harmful situations.

Extensive evidence exists that accounts for the involvement of amygdala in the processing of fear. In a review from 2003, LeDoux is summarizing the roles different nuclei of amygdala are playing in the processing of fear. Amygdala contains key interconnections
with other brain structures, and these reciprocal projections are responsible for defining what
the amygdala does. The lateral nucleus (LA) of amygdala receives auditory sensory input via
the thalamic and cortical pathways. It has been demonstrated that lesions to the lateral
nucleus or to the auditory thalamic outputs to the lateral nucleus leads to impairments in
auditory fear conditioning (LeDoux, 2003). The basal (B) and accessory basal nuclei (AB) of
amygdala receive input projections from the hippocampal CA1 and subiculum regions. Based
on previous studies, LeDoux summarized that damage to these projections or these nuclei
results in impairment of contextual fear conditioning (LeDoux, 2003). The central nucleus
(CE) receives inputs from lateral, basal and accessory nuclei and in turn sends projections to
lateral hypothalamus, peraqueductal gray and to the bed nucleus of stria terminalis of the
hypothalamus. Damage to the connecting pathway between the LA and CE results in
impairment of auditory fear conditioning, while lesions to the neural projections between the
CE and B or AB nuclei impairs contextual fear conditioning.

When an individual is facing danger the most common reactions are a freezing
behavior, increase in blood pressure and increase in heart rate. The role of the freezing
behavior or the motionless state is acquired in order to avoid attack while the physiological
responses (heart rate and blood pressure changes) have the role to help an animal to deal with
the danger (LeDoux, 2003). We can detect fear in other people by looking at their typical
facial expressions with eyes wide opened, changes in vocalization such as tendencies to
scream, or analyzing skin adjustments such as changes in color and piloerection (Garfinker &
Critchley, 2014). Regarding the CE outputs projections to the lateral hypothalamus, damage
to these pathway causes changes in blood pressure but no consequences on freezing behavior
in response to conditioned fear stimuli. Lesions to the projections between CE and
periaqueductal gray affect the freezing behavior in response to conditioned fear stimuli but not
the blood pressure (LeDoux, 2003). It seems that the lesions to the projections between CE
and stria terminalis of hypothalamus have no effect on blood pressure or freezing. What it
does is that it affects the hypothalamic-pituitary-adrenal axis interrupting the conditioned
release of stress hormones from pituitary (adrenocorticotropic hormone) and adrenal
(cortisol) glands (LeDoux, 2003).

All the above mentioned projections to and from the amygdala nuclei are valuable
data that improved our understanding of the neuroanatomical pathways which underlie fear
conditioning. These findings also provided a starting point for the investigation of the
learning process of fearful stimuli at cellular level (Schafe, Nader, Blair & LeDoux, 2001).
Since fear conditioning is a learning process in which an individual or animal learns to
associate CS and US, this paradigm is serving as an ideal starting point to evaluate the
underlying mechanism of acquisition and consolidation of dangerous stimuli (Schafe et al.,
2001). Studies suggest long lasting plastic changes taking place in the lateral nuclei of
amygdala in response to fear conditioning (Schafe et al., 2001). These findings have been
supported by lesions studies to these nuclei, either through permanent or irreversible lateral
amygdala damage, case in which acquisition of new fearful experiences is unable, as well as
the expression of already acquired fear (Schafe et al., 2001).

Given that imaging resolution of the available methods to study the human brain face
limitations, animal studies (specifically rats) provide us with valuable knowledge about
amygdala nuclei involvement in the processing of fear (LeDoux, 2015). Animal studies
pointed towards neuronal plasticity in lateral nuclei of amygdala as being the backstage
mechanism through which the merging of CS and US is possible. In a male rodent fMRI
study performed by Brydges and co-workers, it was showed that lateral amygdala was
activated in response to a fear conditioned stimulus (Brydges et al., 2013). Comparison of
fMRI data and freezing behavior results between the paired (6 males) and unpaired (6 males)
groups of rats revealed that only the rats that were fear conditioned exhibited activation of the
right lateral amygdala, hypothalamus, somatosensory and granular insular cortex (Brydges et al., 2013). This study provided solid evidence for the importance of the lateral amygdala in the process of acquiring a fear conditioned response. In addition, the authors explained that hypothalamus activation is accounted for its importance in mediating behavioral responses in the fear-conditioned group. Given that the somatosensory and granular cortices are important components of the pain processing pathways, their activity in the paired group or rats was expected (Brydges et al., 2013). The neuroimaging results were nicely complemented by behavioral data in which the paired group of rats exhibited a freezing behavioral pattern in response to CS while it the unpaired group did not (Brydges et al., 2013).

In addition to the valuable knowledge on amygdala and fear processing obtained from animal studies or neuroimaging experiments in humans, the crucial role of this brain region has been also documented through lesion studies (Wendling et al., 2015). For instance, Wendling and colleagues performed a facial emotion recognition task for various emotions (surprise, happiness, anger, sadness, fear and disgust) in epileptic patients that suffered neurosurgery in order to diminish seizure outcomes. Two groups of patients, one that suffered anterior temporal lobectomy (ATL) (27 people) and the second group (33 people) that suffered amygdalohippocampectomy (SAH) participated in the study (Wendling et al., 2015). In this study via email, only participants that suffered unilateral neurosurgery more than three years before the actual study and were seizure-free were allowed to participate. Regarding the emotion of fear, it was found that participants that suffered ATL and had their amygdala, hippocampus and adjacent neocortical temporal tissue resected from one hemisphere (either left or right) exhibit difficulties in recognizing fear in the facial expression (Wendling et al., 2015). Moreover, Wendling and colleagues documented that 54.5 % of patients that suffered ATL on their left hemisphere scored lower in recognizing fear in facial expressions compared to control group (30 people). The fact that ATL patients exhibit profoundly worse scores
compared to both control and SAH group indicates that for the interpretation of fear an intact temporal lobe with all its connections is required (Wendling et al., 2015).

Based on the results obtained Wendling and co-authors maintained that the left temporal lobe is more important than the right temporal lobe in the interpretation of fear, claim that is in contradiction with previous studies which found that the right hemisphere damage results in a worse pathology (Benuzzi et al., 2004; Meletti et al., 2009). For example, Benuzzi and co-workers compared patients that suffered right- (n=8) and left- (n=5) anterior temporal lobectomy with control participants (n=14) in a facial emotion recognition task targeted for six basic emotions: happiness, fear, surprise, sadness, disgust and anger. In addition, the group also tested participants for: face matching, facial identity recognition, facial affect selection and facial affect matching. For any of the tasks performed no significant differences were found between the left sided operated patients and the control group. Regarding the right sided operated patients, it was found they were significantly impaired in facial affecting naming task compared to normal participants, while no further abnormalities were found on any of the other four tasks performed (Benuzzi et al., 2004). Their study clearly showed that the right temporal lobe is more important for the interpretation of fearful facial expressions that the left temporal region (Benuzzi et al., 2004).

Same results were also showed by Meletti and colleagues in the facial emotion recognition task performed in three groups of participants: 140 subjects with medial temporal lobe epilepsy, 36 subjects with lateral temporal epilepsy and healthy control group (Meletti et al., 2008). Patients from medial temporal lobe epilepsy group were further subdivided based on MRI data in: participants with bilateral damage to these brain region including hippocampus and/or amygdala, participants with lesions on the left hemisphere and participants with lesions on the right hemisphere. The lateral temporal epilepsy group exhibited lesions located in the lateral temporal cortex (Meletti et al., 2008). Participants were
asked to verbally match the emotional faces with the five basic emotions: happiness, fear, sadness, anger and disgust. Authors reported that the medial temporal lobe epilepsy group was significantly impaired in this emotion recognition task compared to both the lateral temporal epilepsy and control group. In addition, a close analysis between the three subgroups indicated that the less impaired group on the task was the left medial temporal epilepsy group (Meletti et al., 2008). The most impaired group was the bilaterally affected one, followed by the right temporal lobe epilepsy group (Meletti et al., 2008). Furthermore, a comparison between the control and the medial temporal lobe epilepsy group revealed that the latest group of participants was significantly impaired regarding recognition of all negative emotions for which they were screened (sadness, fear, anger and disgust), but not for the positive valence emotion of happiness. Overall, this study indicates that the right amygdala is more important than the left amygdala in the recognition of fear (Meletti et al., 2008).

However, Wendling and colleagues’ results for the importance of the left temporal lobe in recognizing fearful expressions are in accordance with previous findings from patients with anterior temporal epilepsy and children and adolescents with temporal lobe epilepsy (Bonelli et al., 2009; Golouboff et al., 2008). Bonelli and co-workers implemented a fearful face fMRI paradigm to investigate amygdala activation in healthy controls (n=21) versus patients with left (n=26) and right (n=28) temporal lobe epilepsy. In regards to processing fearful face expression stimuli, their study showed that in left temporal lobe epilepsy patients, both left and right amygdalae were significantly reduced in activity compared to both the healthy participants and right temporal lobe epileptic patients. In addition, compared to control group the right hippocampus was significantly less activated in the left temporal lobe epilepsy patients, while significantly reduced activation was detected in bilateral hippocampus in left compared to right temporal lobe epilepsy group (Bonelli et al., 2009).
Similar to Bonelli and colleagues and Wendling and co-workers, another study also suggests a correlation between the left amygdala and processing of fearful facial expressions (Golouboff et al., 2008). The ability to recognize and name the emotions present in facial expressions was tested in children and adolescents with right temporal lobe epilepsy (n=13), left temporal lobe epilepsy (n=16), fronto-central epilepsy (n=8) and healthy controls (n=37). Each facial stimulus mimicked one of the five basic emotions: happiness, sadness, fear, anger and disgust (Golouboff et al., 2008). No significant differences were found between any of the epileptic groups and healthy subjects concerning their ability to recognize sad and angry faces. The ability to recognize fearful faces was greatly impaired in the left temporal lobe epilepsy group (Golouboff et al., 2008). Significant reduced ability to recognize happy face expressions was observed in the fronto-central epileptic patients and reduced ability to recognize disgust was found in right temporal lobe epilepsy. Authors concluded that the results obtained point towards an important role for the temporal lobe structures in the processing of emotions and a crucial role for the left temporal lobe in recognizing fear (Golouboff et al., 2008). Golouboff and colleagues argued that given only left but not right temporal lobe epilepsy group exhibited problems in naming emotions, it could mean that the right hemisphere is important for preverbal abilities (such as coding perceptual information about facial emotion) while the left hemisphere has verbal capabilities such as retrieval of information and naming of emotions (Golouboff et al., 2008).

In contrast to the previously detailed information regarding amygdala and other emotions (regardless of valence) based on fMRI studies, Wendling and colleagues post-operative study revealed no differences in recognition of happiness, anger and sadness between the patients that suffered neurosurgery and the control group (Wendling et al., 2015).

Although overall the temporal lobe is a generally accepted brain region involved in emotion processing, from the above described results regarding lateralization and recognition
of fearful facial expressions (but not only limited to the emotion of fear) it can be concluded that inconsistencies are present. Regarding this issue we need to take into account the differences in the performed experiments between distinct research groups. Parameters that we need to take into account that might influence the results are: heterogeneity of the patient groups, onset of the epileptic seizures in different patients, frequency and duration of epileptic seizures, and the reason for temporal lobe epilepsy. Furthermore, it would be beneficial to test the participants in the facial recognition task pre- and post- surgery, and to replicate the results between labs taking into account cultural and language differences.

With the above detailed account for the relationship between amygdala and the processing of threatening stimuli, the next question posed was how brain connections are responsible for changing our subjective experiences into emotional ones? Based on previous knowledge on connectivity between different brain regions, LeDoux submitted that in the case of non-emotional stimuli the working memory that relies on dorsolateral prefrontal areas, anterior cingulate and orbital-cortical regions is activated. In addition, sensory processing network that acts as a short-term memory storage place, and the hippocampus which is necessary for long-term (explicit) memory storage are also activated. When an emotional stimulus is presented, as in the case of fear (seeing a bear nearby) the working memory gets signals from the fear system that this brain regions has been activated. In this context, amygdala is sending projections to working memory areas (dorsolateral prefrontal areas, anterior cingulate and orbital-cortical regions), but also to the sensory processing system (LeDoux, 2003). It has been proposed that the higher number of inputs to working memory (from amygdala) in the case of emotional stimuli as compared to non-emotional stimuli (no inputs from amygdala) makes the difference between a subjective experience and an emotional one (LeDoux, 2003).
Furthermore, LeDoux recently submitted that two different brain mechanisms exist: one non-conscious mechanism that is responsible for detecting significant dangerous stimulus and to respond to this emotional stimulus, and a second brain mechanism that exists to create the subjective feeling of fear (LeDoux, 2012, 2015). While the author comes to write about the importance of understanding consciousness in order to understand emotions, he ascertains that by treating the above mentioned two brain mechanisms as distinct, scientific knowledge gained from experiments on animals can be applied to affective studies in humans (LeDoux, 2000, 2015). LeDoux stretches the importance and existence of a brain mechanism named survival system which is evolutionary inherited from animals to humans. This survival mechanism is said to have two important features: it has the ability to consciously detect dangers to our (or other animal) wellbeing and the capacity to respond to these threats in order to promote survival. This is also applied to reproduction, energy management, or thermoregulation for instance (LeDoux, 2012, 2015). He also emphasizes the need to differentiate this brain mechanism common to humans and other vertebrates and invertebrates, from the emotional (fear in this case) circuit that creates the feeling of fear. In this context, the survival mechanism that gives rise to motive state and emotional behavior do not equal the conscious feeling. What enables conscious feelings to occur is a nervous system with the capacity to consciously experience these motive states. So, in the creation of the feeling of fear, the presence of motivational states that arises from the survival mechanism is required. But, this motivational state needs to be consciously experienced which means that the integration of thoughts and the cognitive working space (working memory) is mandatory (LeDoux, 2015). This is to say that, a defensive motive state (a state triggered by the survival mechanism in response to threatening stimuli) gives rise to the components needed for the construction of the emotion of fear. These include: input from amygdala to cortical areas, brain arousal, body feedback, and initiation of goal-directed behavior (LeDoux, 2015). These
components can be triggered in all animals, conscious or non-conscious. Attention is what enables these ingredients to enter the cognitive working space. In the working space the long-term memory information stored about the external stimulus work along the various components that enter the working memory in order to give rise to the feeling of fear. Relying on the existence of the two brain mechanisms, one non-conscious and the second conscious, affective neuroscience can advance and acquire knowledge on emotions from both human and animal studies (vertebrates and invertebrates). In this way, the emotions are considered to arise from non-emotional components that enter consciousness therefore creating the feelings. The feeling of fear is considered to arise in a bottom-up pattern, being created from motive states (triggered by survival mechanism) that enter consciousness through attention. In contrast, social emotions such as compassion, shame, fear of failing in life (a different kind of fear than being of a bear) or pride arise from cognitive processes therefore are constructed in a top-down pattern (LeDoux, 2015).

In conclusion, the aforementioned experimental results are clearly suggesting a crucial role for amygdala in the acquisition and expression of emotional experiences. Although both negatively and positively valenced emotions are correlated with amygdala activity, the role of amygdala in processing external fearful stimuli is well documented by the scientific literature. While inconsistencies are observed regarding the obtained results between different research groups regarding lateralization studies, one must take into account methodological limitations, different parameters taken into account and analyses strategies. Granting the role of amygdala when facing threatening stimuli, the importance of understanding the mechanisms that supports emotional experiences needs to be further investigated.

I believe that studies that can be replicated between different research groups are the key to get to a common ground. While valuable knowledge has been gained when scientists
held different opinions and theories, I believe now is the time to work together in order to get to the bottom of what is the neural mechanisms that supports our emotions. Furthermore, only by having a deep and clear idea of the emotional network that underlies our affective states, different therapies can be constructed for people that suffer from emotional disturbances and have self-regulatory problems. On the theme of self-regulation, the next chapter has the aim to unravel the affective neural machine that underlies the process of emotion regulation, emphasizing on the reappraisal strategy and the link between amygdala and PFC regions.

Although, the experiments described in this chapter result in different outcomes leading some scientists to disagree with the involvement of amygdala in the emotions fear, the vast majority of neuroimaging data suggest that amygdala is crucial for the identification and expression of fear. In relation to this, the next chapter has the aim to describe further how amygdala’s activity is top-down regulated by cortical regions. This goal will be achieved by describing the process of cognitive reappraisal as a strategy to regulate negative emotions, and by outlining some of the most recent neuroimaging data that found a correlation between cortical regions, amygdala and a decrease in negative emotions.

**Emotion Regulation/Self-regulation**

Emotions are key components in our daily life which allow us to adjust our reactions and behavior in face of major challenges. Since emotions are central to our lives the importance of getting to understand how to regulate our emotional experiences is crucial. We can assume that we are constantly regulating our emotional experiences since only some high arousing emotional stimuli results in fully blown emotions. An example would be for instance an upsetting feeling due to high volume music from certain public places which we might chose not to let it develop in a fully angry or annoyed emotional state. This can be achieved via emotion suppression. But emotion regulation (ER) refers also to shifting away the attention from negative stimuli for instance towards more positive ones, in the case of
depressed people which keep diaries in order to overcome their sorrow and extreme sadness. Emotion regulation is a rapidly advancing field of study in which neuroscientists and psychologists work together to bring benefits in strategies applied to individuals with self-regulatory problems. There are a variety of mental disorders such as anxiety disorder, bipolar disorder and mental depressive disorder (MDD) in which an individual is unable to normally regulate their emotional experiences, therefore the need for the knowledge and understanding of this research field is well deserved (Amstadter, 2008; Berking, Ebert, Cuijpers & Hofmann, 2013; Gruber, Hay & Gross, 2014). Because negative emotions can undermine our goals and plans and have been shown to be more difficult to modulate and control compared to positive emotions, it is very important to understand how to regulate them effectively. For this a thorough understanding of the neural bases of ER is essential.

One of the most studied cognitive strategies for emotional regulation is cognitive reappraisal. The appraisal consists in the evaluation of external or internal stimuli which can be found either irrelevant for the individual or with a high significance. In case stimuli are appraised as meaningful, the generally accepted sequence of events that follow consists of the emotional response, and the increase or decrease in physiological signs that ultimately lead to changes in behavior. The appraisal has two branches: a first appraisal round in which the stimuli are evaluated as positive, negative or irrelevant for an individual’s wellbeing. The second appraisal further takes into consideration resources that can help the individual in coping with the situation. As mentioned in the latter section, LeDoux (2000) argues that appraisal can follow one of the two brain pathways available. An indirect, long, slower, and conscious brain road, advantageous for a detailed evaluation of stimulus and which consists of information passing through cortex and hippocampus. In the second brain pathway, the information passes directly from the sensory thalamus to amygdala, making this road faster and shorter with benefits for life and death circumstances (LeDoux, 2000). An important note
when considering the two brain pathways is that emotional experiences can result even before cognitive processes take place. The reappraisal component takes into consideration the primary and secondary appraisal steps and uses the information about the stimuli and the resources in order to modulate them if needed. Hence, in the reappraisal process the significance of the external or internal stimulus is reevaluated so that the triggered emotional response is influenced to a lesser extent by the reinterpreted stimulus (Ochsner & Gross, 2005). An example would be to reinterpret the situation of attending an interview not as a stressful test that one needs to pass in order to obtain a position but as an opportunity to receive feedback, improve and obtain more details on the actual institution and position. Given that successful reappraisal of negative stimuli has been associated with a better interpersonal functioning, improved social outcomes and higher levels of wellbeing, this section is concerned with the neuroimaging experiments that reveal the neural bases of negative stimuli reappraisal (Gross, 2002; Gross & John, 2003; Mak, Hu, Zhang, Xiao & Lee, 2009).

In short terms, emotion regulation is defined as a person capacity to deliberately maintain, up-regulate or down-regulate an emotional experience in order to results in higher well-being (Kalisch, 2009; Lazarus & Alfert, 1964). Emotion regulation works by targeting attention, knowledge and physiological responses with the aim of satisfying hedonic desires and reach the proposed goals (Koole, 2009). This regulation can be intrinsic and refers to how emotion itself is regulated or extrinsic which refers to the process by which we regulate our emotions with the aim to regulate other people’s emotions. Koole regards the roles of the ER directed towards an individual’s needs, goals or person (Koole, 2009).

Gross and Thompson (2007) proposed a model by which emotion regulation can occur. This model encompasses five different ways by which emotion regulation can take place: situation selection, situation modification, attention deployment, cognitive change and
response modulation. From the five categories, situation selection and modification are strategies that allows for regulation of a possible emotional experience before this has occurred (Gross & Thompon, 2007; Ochsner, Silvers & Buhle, 2012). Attention deployment, cognitive change and response modulation are regulation strategies that can occur once the emotional experience had already begun (Gross & Thompson, 2007).

In the following discussed paragraphs the focus will be on the neural correlates of cognitive reappraisal as the potential mechanism to regulate emotional experiences. Taking into account the previously described experiments in which amygdala has been found to correlate with a wide range of emotions (most prominently with fear), the next posed questions is which brain regions modulate amygdala’s activity and therefore leads to emotional regulation? The aim here is to provide an integrative review about neuroimaging studies that support the hypothesis of a correlation between the PFC and amygdala in successful emotional regulation through reappraisal.

In their article on cognitive emotion regulation through the neural connections between the prefrontal regions and subcortical structures, Wager and colleagues provided evidence for two independent networks that account for the successful reappraisal: a mediating and a direct pathway (Wager, Davidson, Hughes, Lindquist & Ochsner, 2008). In the so called mediating pathway, the prefrontal cortex modulates the activity of different subcortical structures which account for the reappraisal of external and internal emotionally charged stimuli, therefore regulating the emotional experience (Eippert et al., 2007; Goldin, McRae, Ramel, & Gross, 2008; Silvers, Wager, Weber & Ochsner, 2014; Urry et al., 2006; van Reekum et al., 2007; Zhang, Guo, Zhang & Luo, 2013). In the direct pathway, successful reappraisal is directly linked to the cortical activity itself, and to a less extent to the impact of the prefrontal cortex on subcortical structures (Barrett, Mesquita, Ochsner & Gross, 2007). If we consider the cortical-subcortical modulation pathways as valid, this means the neural
correlates for negative emotions (fear, anger, sadness), meaning amygdala, is the structure whose activity is influenced in the process of successful reappraisal. Another hypothesis is that in the case of positive emotions, the prefrontal cortex is expected to influence subcortical structures such as nucleus accumbens and ventral striatum (Wager et al., 2008). The results from a voxel-by-voxel study revealed that indeed the amygdala activity is influenced in the case of successful reappraisal of negative stimuli. Also, the nucleus accumbens and ventral striatum which were brain regions mostly associated with positive emotions were found to be the targeted neural networks for the reappraisal process of positive affect (Wager et al., 2008). The cortical region mostly associated with the reappraisal process was the right ventrolateral prefrontal cortex (VLPFC) which in the case of negative affect is exerting its influence on the amygdala dampening its activity and therefore reducing the experience of negative emotions (Wager et al., 2008; Nelson, Fitzgerald, Klumpp, Shankman & Phan, 2015). Further neuroimaging studies provide evidence for the activation of PFC which is coupled with a decreased activity of amygdala as the neural mechanism through which the cognitive reappraisal takes place (Kalisch, 2009; Mak et al., 2009; Nelson et al., 2015; Ochsner et al., 2012; Phillips, Ladouceur & Drevets, 2008; Zhang et al., 2013). The meta-analysis study performed by Kohn and colleagues (2014) indicates that VLPFC has a critical role in reappraisal since it has direct anatomical connections to amygdala, region that in turn sends afferent connections to insula and back to VLPFC (Kohn et al., 2014).

A more recent fMRI study also revealed a correlation between the PFC and amygdala (Sarkheil et al., 2015). In their study, Sarkheil and co-workers divided 14 participants into two groups: 8 participants (6 females and 2 males) in the feedback or ‘regulate’ group and 6 participants (2 females and 4 males) in the control or ‘view’ only group. While fMRI scanning took place, participants from the ‘regulate’ group were asked to observe aversive pictures presented in blocks of three (each stimulus picture held for 4.5s) and cognitively
reevaluate the image. The control group was asked to observe the same blocks of aversive images and count down from 900 in order to allow abandonment of uncontrolled mental processes (Sarkheil et al., 2015). The analysis revealed that in response to the cognitive reappraisal effectuated, the activity of the right and left amygdala were significantly lower than on control participants which had normal amygdala activity (meaning higher) in response to aversive images. The left prefrontal cortex (LPFC) was activated a bit more during reappraisal phase, although not significantly more than in the control participants. The correlation studies showed a substantial negative correlation between LPFC and right amygdala but not left amygdala in response to stimulus reinterpretation (Sarkheil et al., 2015). In conclusion, this study clearly demonstrates that left PFC plays a role in reducing amygdala’s activity during cognitive reappraisal, hence dampening our response to aversive negatively valenced stimuli (Sarkheil et al., 2015). Nelson and co-authors (2015) also provided strong fMRI results that support the involvement of PFC regions in successful cognitive reappraisal of aversive faces. These results are in contradiction with data from another fMRI study (Döerfel et al., 2014). Döerfel and colleagues found that negative emotions are regulated via distraction, detachment, and expressive suppression, cases in which the right prefronto-parietal cortex exerts its regulatory effects on left amygdala, dampening its activity therefore controlling the emotional experience. Contrary to Sarkheil and colleagues (2015), during cognitive reappraisal of aversive imaging stimuli the left VLPFC and orbitofrontal gyrus were activated, with minimal effect on amygdala’s activity (Döerfel et al., 2014). Another imaging experiment performed by Kim and Hamann (2007) also failed to observe any down-regulation of amygdala in the process of reappraisal of negative stimuli. Failure to detect amygdala activation during cognitive reappraisal was also reported by other studies (Johnstone, van Reekum, Urry, Kalin & Davidson, 2007; Urry et al., 2006).
Moreover, in the neuroimaging investigation by Nelson and co-workers (2015) different results were obtained. In their study 22 female participants, with age between 18 and 55 took part in three tests: look-neural, maintain-negative and reappraise negative (Nelson et al., 2015). Authors concluded that reappraising strategy correlated with a greater activation of left DLPFC, left mPFC, and bilateral VLPFC supporting the involvement of these cognitive regions in reappraisal. It was reported that a decrease in negative affect in response to reappraisal was associated with a decrease in left DLPFC and increase in bilateral amygdala activity (Nelson et al., 2015). The decrease in left DLPFC was unexpected given previous contradictory experiments, but the authors explained that because the reappraisal was successful and the negative affect was diminished, so was the need for this cognitive control area (Nelson et al., 2015). Additionally, and contrary to the generally accepted view that amygdala activity is diminished during reappraisal, Nelson and co-authors reported a greater activity in bilateral amygdala in response to reappraisal. They explained that given that the stimuli used are bottom-up generated and there is a need for the generation of a context and linguistic representation, this could account for the observed increment in amygdala’s activity (Nelson et al., 2015; Otto, Misra, Prasad & McRae 2014).

Of course, all these discrepancies in the obtained results need to be critically reviewed and compared since the experimental parameters differ from one research group to another. For instance, reevaluation strategy was correlated with an increase in orbitofrontal cortex (OFC) activity, and a decrease in amygdala’s activity which ultimately led to dampening of negative affect (Banks, Eddy, Angstadt, Nathan & Phan, 2007). But in Döerfel’s study (2014), although the increased activity in OFC was observed during reappraisal, this was not correlated with a decrease in amygdala’s activity. This might be due to a number of reasons.

One cause could be that compared to other ER strategies, reappraisal is a more complex mechanisms which assumes the involvement of a greater number of brain structures,
which in turn increases the differences between different participants and therefore led to the
different results obtained (Döerfel et al., 2014). Another parameter that should be taken into
consideration is the time when picture were rated. Post-hoc rating resulted in no amygdala
activation during reappraisal in Döerfel and co-workers (2014) while the in-scan ratings
allowed Banks and colleagues (2007) to detect amygdala down-regulation as the neural
substrate that led to successful reappraisal. Number of participants from each group (control
over appraisal group) should also be closely controlled in order to avoid false results together
with a distinction between males and females. Mak and colleagues performed an fMRI
imaging experiment comparing 12 female and 12 male participants with the aim to
investigate neural underpinnings of positive and negative ER. In both females and males,
during reappraisal of negative images the left anterior cingulate gyrus was strongly activated
compared to view only condition. It was shown that successful reappraisal of negative stimuli
in females implies down-regulation of insula and amygdala’s activity, correlation that was
not observed in males (Mak et al., 2009). In another study, Nelson and co-workers reported
an increased amygdala activity correlated with negative stimuli reappraisal which is
inconsistent with the general accepted view that during reappraisal amygdala’s activity
should be diminished (Nelson et al., 2015). But as the authors mentioned in their article,
methodological limitation such as the fact that the study was created as a single block that
comprised appraisal and reappraisal, could account for the increased amygdala activity
(Nelson et al., 2015). Given the appraisal and reappraisal were correlated with brain regions
in the same experimental block it could be that what the researchers observed was actually
the amygdala’s response to the initial appraisal. Another plausible explanation is that the
amygdala was activated because the attention also increased as the aversive stimulus needed
to be reappraised (Nelson et al., 2015). One more factor that could compromise the obtained
results could be the number of sample size for each group which could not be sufficiently
large in order to allow identification of all recruited brain regions during reappraisal. For instance previous cognitive reappraisal studies pointed towards increased activity in anterior cingulate cortex (ACC), findings which were not replicated by Nelson et al. (2015).

Peripheral measures such as skin conductance, heart rate and eye tracking should be implemented in order to confirm the occurrence of the reappraisal process correlated with the activated and deactivated brain regions. Last but not the least researchers should also take into account the strategy by which participants cognitively reappraise the stimuli (reinterpretation, objectification, suppression).

Even if PFC has been found to be consistently implicated in reappraisal, the specific activated regions differ as explained above. Being clear about the specific strategy (reinterpreting or distracting) the participant is using to reappraise the stimulus may shed light and account for the differences observed. Ochsner et al., found that a reinterpreting method is correlated with lateral PFC that accounts for externally focused processing while adopting the distracting strategy when reappraise a stimulus has been found to activate medial PFC, region involved in internally focused processing (Ochsner et al., 2004).

Although an unanimated accepted network for how emotions are regulates is still up for debate, the involvement of the PFC in the experience of emotions is very clear. PFC considered necessary for higher cognitive processes, is also implicated in certain aspects of emotional experiences (Kalisch, 2009; Kohn et al., 2014; Mak et al., 2009; Nelson, et al., 2015; Ochsner et al., 2012; Otto et al., 2014; Phillips et al., 2008; Sarkheil et al., 2015). The goals we have in our lives are controlled and sustained by PFC areas. This region is activated in response to affect guided anticipation. This means that PFC enables us to handle difficult and competitor situations by allowing us to anticipate positive incentives in order to continuously redirect behavior to achieve the goals we have. This goal directed mechanism is disrupted in certain disorders such as depression. Symptoms of depressions such as the
inability to self-encourage and motivate to work to achieve goals and aims, seems to point towards a correlation with activity abnormalities of the VMPFC (Davidson, 2003). A decreased PFC activation also leads to maintenance of the current negative affect and attitudes in depressed individuals.

Moreover, other study point toward different roles for right and left PFC regions (Davidson & Irwin, 1999). The right PFC has been correlated with withdrawal behavior in front of negative situations. The activation of the inferior frontal sulcus of the right lateral PFC has been linked to withdrawal behavior, while the lateral right orbitofrontal cortex (OFC) has been found to be activated in punishments (Davidson, 2003). As opposed to right PFC that is implicated in withdrawal behavior, the activation of the left PFC is correlated with the trigger of approach and guidance of behavior towards achieving goals. The left medial OFC has been found to be activated in response to rewards, which in depressed individuals is expected to be hypoactivated (Davidson, 2003).

Given that reappraisal is an evaluation mechanism the involvement of the several PFC regions important for cognitive control processes mentioned in this section is quite clear. The VLPFC is important for working memory, selective attention and expectation of the emotional stimuli (Kohn et al., 2014; Nelson et al., 2015; Okon-Singer, Hendler, Pessoa & Shackman, 2015; Otto et al., 2014). The DLPFC is implicated in attention, is involved in supporting goal oriented behavior, response selection and reward processing, and is important for working memory (Kohn et al., 2014; Nelson et al., 2015; Okon-Singer, Hendler, Pessoa & Shackman, 2015; Otto et al., 2014).

In summary, the above described neuroimaging experiments suggest that in the process of cognitive reappraisal the increased activation of cortical regions is coupled with the decreased activity of the amygdala. This process has been found to be linked to a decrement in the negative emotions and therefore cognitive reappraisal is used as a successful
therapeutic strategy for patients with depression, borderline personality disorder and other pathological states.

**Conclusions**

Emotion is a common term used in our everyday language that slowly has entered the scientific world. Although various attempts have been made to define emotions, these states do not have yet a well-defined concept. But given the importance of emotions in such a great variety of situations in our lives, science had to overcome the lack of a single and clear definition and advance in understanding emotions from their roots. What is clear is that emotional experiences arise when an individual’s well-being is influenced by external or internal stimuli that have relevance for the person. For instance, stimuli than intervene with our plans and goals are responsible for generating our emotional states. That is not to say that the stimulus itself is responsible for the generated experience, but rather our evaluation of the encountered stimulus. This evaluation that in scientific terms is called cognitive appraisal is one of the key concepts that lay at the base of cognitive theories of emotions.

Cognitive theories claim that emotions are multifaceted states that are made of several components: a subjective experience, behavioral (approach or withdraw) and peripheral physiological (heart rate) changes. One important property of emotional states is that these can be cognitively molded and reshaped in order to allow us to adjust and cope with the situations that may arise in order to reach our goals and preserve a higher wellbeing. Two key features taken into account when investigating emotions are valence and arousal. Both negatively and positively valenced emotions are important for humankind. Some of the negative emotions provide information that promote survival and reproduction (e. g. fear which may promote avoidance of a threatening situation) but can also lead to an anxious behavior. Also, an increase in positive emotions and a decrease in the negative ones are considered the key to wellbeing.
Giving a descriptive overview of three of the most fast advancing cognitive theories of emotions, this thesis’ aim was focused on describing the appraisal component of these theories. The neural bases of emotional experiences have been approached mostly through the description of the neural network that supports the negative emotion of fear. Making use of the relevant neuroimaging studies, the role of the amygdala in the generation and expression of fear (but not limited to fear) has been found to be crucial. Lesion studies, animal experiments, and human neuroimaging experiments using fear conditioning paradigm exposed amygdala as a key brain region in the acquisition and manifestation of fear. Moreover, the top-down strategy of reappraisal was used here as a successful emotion regulation method in order to point to the cortical regions (VMPFC, DLPFC, mPFC, OFC) involved in the cognitive control which allowed promotion of wellbeing while decreasing negative affect and negative affect expressive behaviors. By revealing the influence of the so called cognitive brain on the emotional neural network and vice-versa, it can be observed how our brain accounts to adaptive and abnormal behaviors observed when we are presented with emotionally charged situations.

Although the role of amygdala in response to threatening stimuli has been largely elucidated, and a brain network consisting of PFC-amygdala interactions have been found to lead to effective down-regulation of our negative emotions, further neuroimaging studies are needed. The discrepancies and dissimilarities pointed here regarding the neuroimaging results obtained, differences in existing theories, and a lack of a clear concept of emotions and emotion regulation terms, indicate that further investigation is needed. Investigation of genetic factors could shed some light on activity of different brain regions when we perceive and generate emotions. Also, it could be that a combination between EEG and fMRI experiments could further complement our knowledge on the correlates of emotions by overcoming the spatial and temporal boundaries of these methodologies.
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