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***Affective reactions to aversive and appetitive cues:  
Evaluative process and emotional arousal***

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# Contents

## Foreword

## Chapter 1

<b>Introduction</b>	1
What is an emotion?	1
Emotion: from simple action tendencies to motivational systems	3
Evaluation of emotional stimuli: Negativity Bias vs. Emotional Significance	12
Subjective evaluation of emotional stimuli	14
Brain response to emotional stimuli	17
<u>The negativity bias in central indexes of the emotional response</u>	17
<u>Emotional significance and brain response</u>	20
Attentional engagement to emotional stimuli	25
<u>The negativity bias in attentional engagement</u>	26
<u>Emotional significance and attentional engagement</u>	27
Saccadic behavior toward stimuli outside the focus of attention	28
<u>Saccadic behavior and Hedonic Valence: Approach-Avoidance vs. Negativity Bias</u>	29
<u>Emotional significance and saccadic behavior</u>	30
Research Overview	30

## Chapter 2

<b>The Motivational Gradients</b>	33
Experiment 1: Evaluative Categorization of Emotional Stimuli	36
Method	37
Results	40
Experiment 1: Summary	44
Experiment 2: Brain Response to Emotional Stimuli	44
Method	45
Results	49
Experiment 2: Summary	56
Intermediate Summary: The Motivational Gradients	57

Conclusions	57
The next steps: affective attentional bias toward negative stimuli?	58
<b>Chapter 3</b>	
<b>Attentive capture of multiple high-arousing stimuli</b>	59
Experiment 3: Simultaneous presentation of distractor pairs	60
Method	60
Results	63
Experiment 3: Summary	64
Experiment 4: Alternation of distractor pairs	65
Method	67
Results	69
Experiment 4: Summary	70
Intermediate Summary: Attentive capture of multiple high-arousing stimuli	71
Conclusions	72
The next steps: affective bias in saccadic behavior	73
<b>Chapter 4</b>	
<b>Evaluation of emotional stimuli in a dynamic task</b>	74
Experiment 5: Instructed saccades in a dynamic task	76
Method	77
Results	80
Experiment 5: Summary	81
Experiment 6: The effect of expectations on the saccadic response	82
Method	83
Results	84
Experiment 6: Summary	85
Intermediate Summary: Evaluation of emotional stimuli in a dynamic task	86
Conclusions	87
<b>Chapter 5</b>	
<b>General Discussion</b>	85
The Motivational Gradients	89

Attentive Capture of Multiple High-Arousing Stimuli	94
Evaluation of Emotional Stimuli in a Dynamic Task	98
Conclusions	101
<b>Note Section</b>	104
<b>Bibliography</b>	106

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# Foreword

During the course of evolution all animals have developed strategies to detect, recognize, and appropriately react to significant stimuli. The ability to evaluate appetitive and aversive stimuli is a basic process shared across different species. For human beings, the evaluation of good or bad information is one of the most central aspects of everyday life functioning (Alves, Koch, Unkelbach, 2016; Cacioppo, Gardner, Berntson, 1997). The evaluation process requires the dynamic assessment of many positive and negative stimuli within the organism's external and internal environments; our perceptual system, especially the visual sensory modality, makes it possible to know about the occurrence of an external event before the organism comes into contact with it. However, despite the obvious value in appraising both rewarding and harmful stimuli, the matter of whether positive and negative evaluations are given equivalent weight has been of considerable debate (Briggs & Martin, 2008, 2009; Cacioppo et al., 1997; Cacioppo, Berntson, Norris, & Gollan, 2011; Radilova, 1982). In the present experiments, the competing hypothesis that the evaluation is driven by a specific valence category or by the general significance (arousal) of valenced information, independently from the direction of the valence, will be tested. Specifically, the evaluation of natural stimuli will be investigated by using physiological and subjective indexes of the emotional response in order to explore functional differences in the evaluation of positive and negative stimuli in different stages of emotional processing.

# Chapter 1

## Introduction

### What is an emotion?

Even a primary question such as “What is an emotion?” does not have a single answer. Models of emotional response have described the relationship between subjective feelings and physiological response in different ways. In particular, some researchers have emphasized the discrete nature of emotions, together with the specificity of the physiological changes associated with each emotion (Adelmann & Zajonc, 1989; Ekman, Levenson, & Friesen, 1983). In contrast, other researchers have pointed out the important role of cognitive processing such as appraisal in determining the expression and experience of emotion (Frijda, 1986; Schacter and Singer, 1962). Finally, other investigators have emphasized the role of motivation in regulating behavior and physiological functions in human and animals, stressing the importance of basic motivational systems (Blanchard & Blanchard, 2003; Lang et al., 1997; Lang & Davis, 2006; Russell & Barrett, 1999).

Part of the complexity of defining what emotions are derives from the fact that different indexes might provide useful information about different psychological consequences of emotional processing. In order to study the evaluative process several physiological, behavioral, and subjective indexes of the emotional response are used to investigate the functional differences in the evaluation of visual stimuli.

In the next paragraph, the main models describing the motivational functions of emotional perception are described.

## **Emotion: from simple action tendencies to motivational systems**

Whereas the explanatory models of emotional expression vary as a function of the proposed account, evolutionary analysis suggests that the origin of emotional perception dwells in the action that the emotional stimuli implies. Emotions seem to be about doing something, and this is the reason why they are usually associated with highly-motivated behaviors, those that are important for the survival of the organism (e.g., escape, attack, sexual realization).

In human beings, however, the explicit reactions hardly ever actually occur: we do not leave our seat because we are watching a frightening movie, and we do not fight with the boss because he insulted us (we might feel angry). Emotions often seem to occur when actions are delayed or inhibited. Thus, affects are more often instances of disposition toward action rather than acts themselves. Emotional cues can prompt states of heightened, focused attention and behavioral immobility, reflecting central activation and preparation for action.

For many theorists, the simpler action tendencies represent the starting point from which the affects have evolved. The behavior of very primitive organisms can be entirely characterized by two basic responses: approach to appetitive stimuli and withdrawal from aversive stimuli (Schneirla, 1959). Of course, this simple bidirectional goal-related behavior cannot implement the many sub-goals of human beings, who are more creative and adaptive in order to interact with the complex environment in which we live.

Although emotional expression is highly varied, the view that it has a two-factor motivational organization is increasingly supported. Konorski (1967) was a key figure in the attempt to understand the relationship between motivation, emotion, and cognition. Starting from the topology of unconditioned reflexes, he focused on their motivational roles. He classified exteroceptive reflexes into two categories: preservative (e.g., ingestion, copulation) and protective (e.g., withdrawal or rejection of noxious agents). Konorski further suggested that drives are the processes that control basic preparatory activities and guide the organism to the accomplishment of consummatory reflexes or protect it from harm. In his view, emotions are the subjective experiences corresponding to particular drives and become familiar to humans through introspection. Dickinson and Dearing (1979) developed Konorski's dichotomy into two opposing motivational systems, aversive and attractive, activated by a wide range of unconditioned stimuli. Additionally, it has been proposed that the aversive and appetitive systems have reciprocal inhibitory connections that affect perception and learning (e.g., Konorski, 1967).

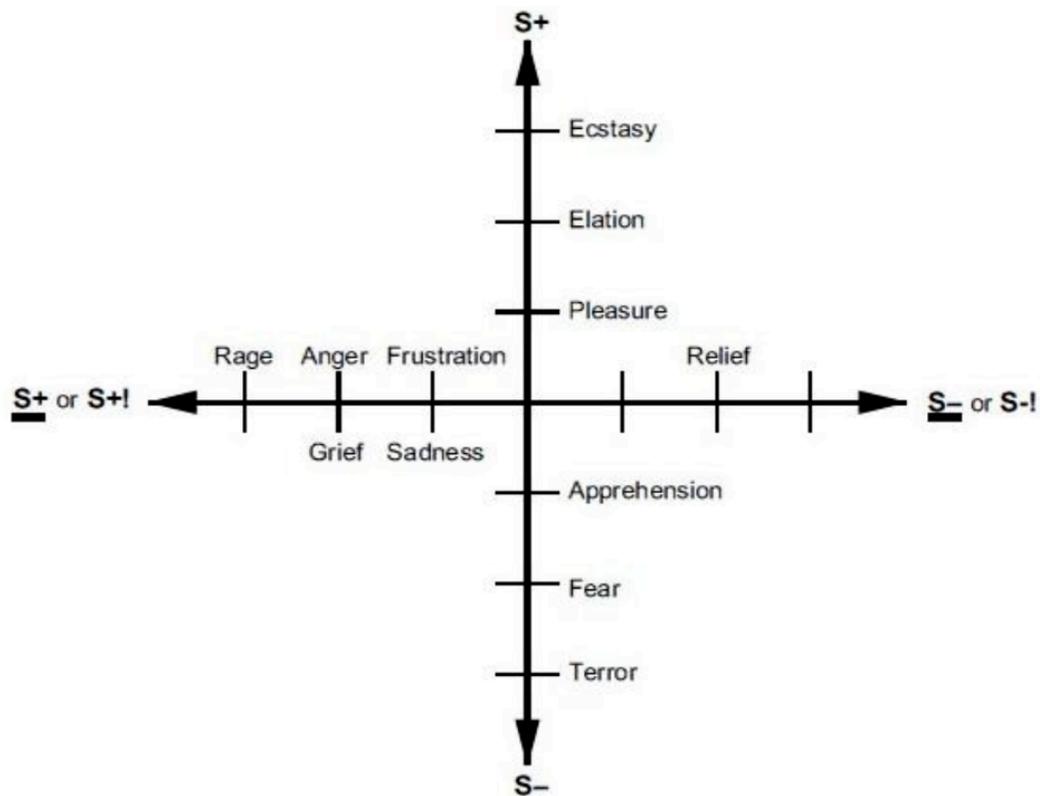
The view that affects might be organized by overarching motivational factors has also been suggested by several researchers who have focused on verbal reports of emotions, beginning with Wundt (1896). Despite the large number and diversity of emotional words, several studies on emotional/evaluative language have consistently found a superordinate division between positivity (pleasant states) and negativity (unpleasant states). Osgood and his associates (e.g., Osgood, Suci, Tannenbaum, 1957) used the semantic differential to show that emotional descriptors were primarily distributed along a bipolar dimension of affective valence, ranging from attraction and pleasure to aversion and displeasure. A dimension of activation, that varies from calm to aroused, also accounted for substantial variance. A similar conclusion has been drawn by other investigators of verbal reports (e.g., Mehrabian & Russel, 1974; Russel, 1980; Tellegen, 1985).

Although it is clear that approach and avoidance have become more varied in man, the strategic frame of appetitive and aversive systems, nevertheless, remains fundamentally relevant. Lang, Bradley and colleagues proposed that two motivational systems exist in the brain, appetitive and aversive-defensive, accounting for the primacy of the valence dimension in affective expression. In this conceptualization, arousal is not viewed as having a separate substrate, but rather, as representing metabolic and neural activation of either the appetitive or the aversive system, or the activation of both systems (see also Cacioppo and Berntson, 1994). Although the tactical demands of the context may shape the emotional expression, all emotions are organized around a motivational base.

The complexity of natural language, and the causal role attributed to feelings, has been a considerable topic of debate since the 19<sup>th</sup> century. A fundamental contribution to this debate was provided by William James (1894): contrarily to the hypothesis that emotional feelings are the beginning of the emotional response (Wundt, 1986), James suggested that emotional feelings are secondary phenomena prompted by the perception of somatic and visceral changes that are elicited by external stimulation. The main idea that James shared with Lange was that emotion does not begin with the conscious experience of a feeling, but that bodily and behavioral responses generate the consequent affect. Even though the idea of specific physiological patterns of response for different emotional sets did not receive substantial support, the important contribution of James in undermining the causal role of feelings in the emotional response continues to be a key concept in the literature.

Nowadays, however, natural language continues to be a critical factor in the emotional response. In fact, due to the complexity of natural language, several authors have tried to focus on the functions of

the emotional response without necessarily describing subjective feelings. Recently, Rolls (2005) proposed that emotions can be described as states elicited by reward, punishment, and their specific functions. These functions mainly involve working to obtain or avoid reward and punishment. From this perspective, an example of emotion might be the happiness produced by winning a large amount of money, or the fear produced by hearing the voice of someone screaming. More generally, Rolls suggested that emotions can be induced by the delivery, omission or termination of rewards and punishments. This approach allows to define and classify emotion in terms of the rewards and punishments received, omitted or terminated (Rolls, 1999). Rolls described some types of emotion that may be elicited by different contingencies (see Figure 1.1). The classification scheme created by the different reinforcement contingencies consists of: (1) the presentation of a positive reinforcement (S+); (2) the presentation of a negative reinforcement (S-); (3) the omission of a positive reinforcement (S+) or the termination of a positive reinforcement (S+!); and (4) the omission of a negative reinforcement (S-) or the termination of a negative reinforcement (S-!).



**Figure 1.1.** Different types of emotion elicited by contingencies; intensity increases as we move away from the center of the diagram.

An important part of Roll's theorization is the formalization of two processes involved in emotional behavior. The first process is stimulus-reinforcer association learning; emotional states are produced as a result. This process is implemented in structures such as the orbitofrontal cortex and amygdala (Grabenhorst & Rolls, 2011; Rolls & Grabenhorst, 2008). The second process is the instrumental learning of an action made to (1) approach and obtain the reward, or to (2) avoid or escape from the punishment. This action-outcome learning involves brain regions such as the cingulate cortex when the actions are guided by the aims, and the striatum and part of the basal ganglia when the behavior becomes automatic and habit-based, that is, uses stimulus-response connections (Rolls, 2005; Rushworth et al., 2011). Emotions are the results of these two processes, because they are elicited in

the first stage by stimuli which are decoded as reward and punishment. The motivation is to obtain the reward or avoid the punishment (the aims for the action). Indeed, primary or unrelated rewards and punishment are specified by genes which determine the aim for action (Rolls, 2013).

Another interesting conceptual framework has recently been proposed by Joseph LeDoux (2012). LeDoux suggested that focusing on the subjective feelings in the motivational response might be misleading. For this reason, he proposed some key phenomena related to emotion without explaining or defining what emotion means. In natural language, some mental states associated with feelings are usually called emotions, leading to an interchangeable use of the words to describe “emotions” and “feelings”. LeDoux highlights the fact that problems might arise when using words connected with “feelings” (fear, happiness, sadness, etc.) to study emotion. The major complication derives when applying these words to the animal world.

In the past decade, neurobiological approaches have, in fact, used animal research to understand emotional functions in the human brain. LeDoux suggested setting apart the general definition of emotion, and considering some important emotional phenomena that are shared by humans and other animals. These phenomena include responses that happen when an organism is in the presence of danger or of the possibility of a reward, both significant events.

LeDoux’s idea is to focus on the circuits mediating the functions that drive an organism to ensure survival by detecting and responding to challenges and opportunities. These survival circuits and their adaptive functions are shared by all mammals, and have originated from early life forms. Regarding the development of the motivational systems starting from simple action tendencies, as previously discussed in this paragraph, the evolution of complex organisms has increased the complexity of the survival circuits, leading them to regulate bodily functions and interactions with the environment.

Following LeDoux's reasoning, survival circuits are not considered to have a causal role in determining feelings, but rather to influence feelings in an indirect way. The function of the survival circuits is to mediate behavioral interaction in specific situations, helping organisms for adaptive purposes. These behavioral interactions are mainly related to the approach-avoidance pattern.

The approach-avoidance motivation usually takes place in two stages: (1) an anticipatory-exploratory search for target objects, and (2) the performance and consummatory responses (innate responses controlled by survival circuits) once target objects are usable (Berridge, 1999, 2007; Cacioppo et al., 1997; Cardinal et al., 2002; Tinbergeb, 1951). Specific target objects activate survival circuits based on innate programming or past experiences. Innate programming derives from a genetically-specified synaptic disposition which is founded by natural selection. Past experiences derive from situations formed by an association of meaningless stimuli with significant events. Thus, meaningless stimuli acquire the capacity to activate the same survival circuits underlying the innate stimuli (LeDoux, 2012). In other words, innate (unconditioned) triggers activate innate responses without the necessity of past exposure to the stimulus to process challenges and opportunities indicated by innate triggers. On the other hand, learned (conditioned) triggers activate innate responses to stimuli after their association with innate triggers (by Pavlovian conditioning), in order to process challenges and opportunities indicated by learned triggers. In general, innate and learned stimuli can be considered in terms of unconditioned and conditioned survival circuit triggers. Moreover, the unconditioned and the conditioned survival circuit triggers can also be described as incentives, stimuli that cause instrumental behavior. More specifically, innate (unconditioned) incentives enhance behaviors of approach or avoidance toward the stimulus, in order to determine specific challenges and opportunities. Learned (conditioned) incentives conduct behaviors toward circumstances where challenges and opportunities can be determined.

In addition, the unconditioned survival circuit triggers can be accounted for as reinforcers, that is, stimuli that increase the probability that an instrumental behavior will be learned (reinforced) and also performed (motivated), supporting the learning of Pavlovian or instrumental associations. Reinforcement and motivation are two strongly related concepts. Situations that motivate are usually reinforcing, and the other way around. Furthermore, if certain situations have been experienced repeatedly by the individual, responses to these situations become habitual and might substitute the incentive instrumental behaviors (LeDoux, 2012).

The effect of survival circuit activation is “generalized arousal” (Lang, 1994; Lindsley, 1951; Moruzzi & Magoun, 1949; Schober et al., 2011). As previously mentioned, generalized arousal has been considered a relevant factor in many theories of emotion (e.g., Lang, 1994; Schacter & Singer, 1962; Schacter, 1975), and is also central to contemporary dimensional theories of emotion (Russel, 1980, 2003; Russel & Barrett, 1999). Generalized arousal is usually triggered in emotional situations, and might affect further processing.

Based on this idea, LeDoux summarizes a series of arousal reactions in response to the activation of survival circuit systems: (1) innate behavioral (related to the specific situation), autonomic nervous system and hormonal responses in which feedback to the brain contributes to the generalized arousal; (2) Excitability and neurotransmission in the brain from the activation of neuromodulatory systems; (3) the activation of motivational systems, depending on goal-directed instrumental behaviors; (4) the contribution of sensory, cognitive, and memory systems according to which new learning, memory representations, and learned instrumental behaviors pertinent to the adaptive function are formed as the individual’s organism becomes susceptible to significant stimuli in the environment. In LeDoux’s perspective, emotion, motivation, reinforcement, and arousal are strongly related arguments that appear together in reasoning about emotion.

LeDoux's model does not take into account many indexes of emotional response. As the motivational model suggests, emotions result from the synergic contribution of language, behavioral, and physiological responses (Lang, 1979, 1985, 1994; Lang, Bradley, & Cuthbert, 1990). This interplay infers an underlying organizing factor (Lang, 1997). The conditioning literature of the 20th century indicates that this factor is biological and motivational. In line with Konorski (1967) and other Pavlovian researchers, emotions are activated by appetitive states, producing positively valent, such as approach and nurturant, responses, and by aversive states, producing negatively valent, such as defensive and protective, responses. Consistent with this perspective, human emotion is considered as having an innate disposition to action (Frijda, 1986; Lang, 1979, 1985), in order to detect and react to events that threaten or sustain our life. In other words, emotions arise from the activation of the motivational circuits, which have engaged sensory systems, enhanced vigilance, and activated reflexive autonomic and motor responses in reaction to threats or rewards in the course of evolution. The defense system is engaged in situations that threaten the survival (e.g., flight, fight, and damage). On the other hand, the appetitive system is activated in contexts that promote survival (e.g., sustenance, copulation, and nurturance). Despite some reactions being only appetitive or defensive, it has been observed that many physiological and behavioral responses are analogous in both situations of arousal, and are supported by the same neural structures (Lang, 2010).

Thus, despite the existence of a great number of emotional words, a really simple structure of affective language has arisen. The type of system that is more greatly activated by an external stimulus is determined by its hedonic valence. The intensity of activation of the two motivational systems depends on the amount of arousal elicited by a stimulus (Bradley et al., 2001).

## **Evaluation of Emotional Stimuli: Negativity Bias vs. Emotional Significance**

Regardless of the model used to describe and explain the function of the emotional response, there is a shared process that brings together different proposals: the evaluative process. In fact, the ongoing ability of an organism to appropriately evaluate its environment is essential to both its well-being and its continued survival.

Rapid evaluations of whether a stimulus is helpful or dangerous are crucial to the correct and timely execution of motivated behavior: for example, to approach a potential reward or flee from a potential threat. The increasing data suggesting that this type of value-related processing in humans and other mammals reflects the activity of the aversion- and appetitive-related motivational substrate (Cacioppo et al., 1997; Hayes and Northoff, 2011; McBride et al., 1999; O'Doherty, 2004) has led to considerable debate as to whether positive and negative evaluations are given equivalent weight in judgments (Briggs & Martin, 2008, 2009; Cacioppo, Berntson, Norris, & Gollan, 2011; Radilova, 1982).

The present work is focused on the differences in the evaluative process, in order to investigate whether the basic evaluation is driven by a specific valence category or by the general significance (arousal) of valenced information, independently from the direction of the valence. The most influential and representative of the former assumption is the evolutionary-based negativity bias hypothesis, a pervasive phenomenon across different cognitive domains (Cacioppo et al., 1997; Rozin & Royzman, 2001; Taylor, 1991). Many authors have suggested that humans and animals process negative and positive information differently; this difference in terms of valence can be summarized by the observations that “bad is stronger than good” or “negative information weighs more heavily”, meaning that negative information has a stronger psychological impact (e.g., learning, social

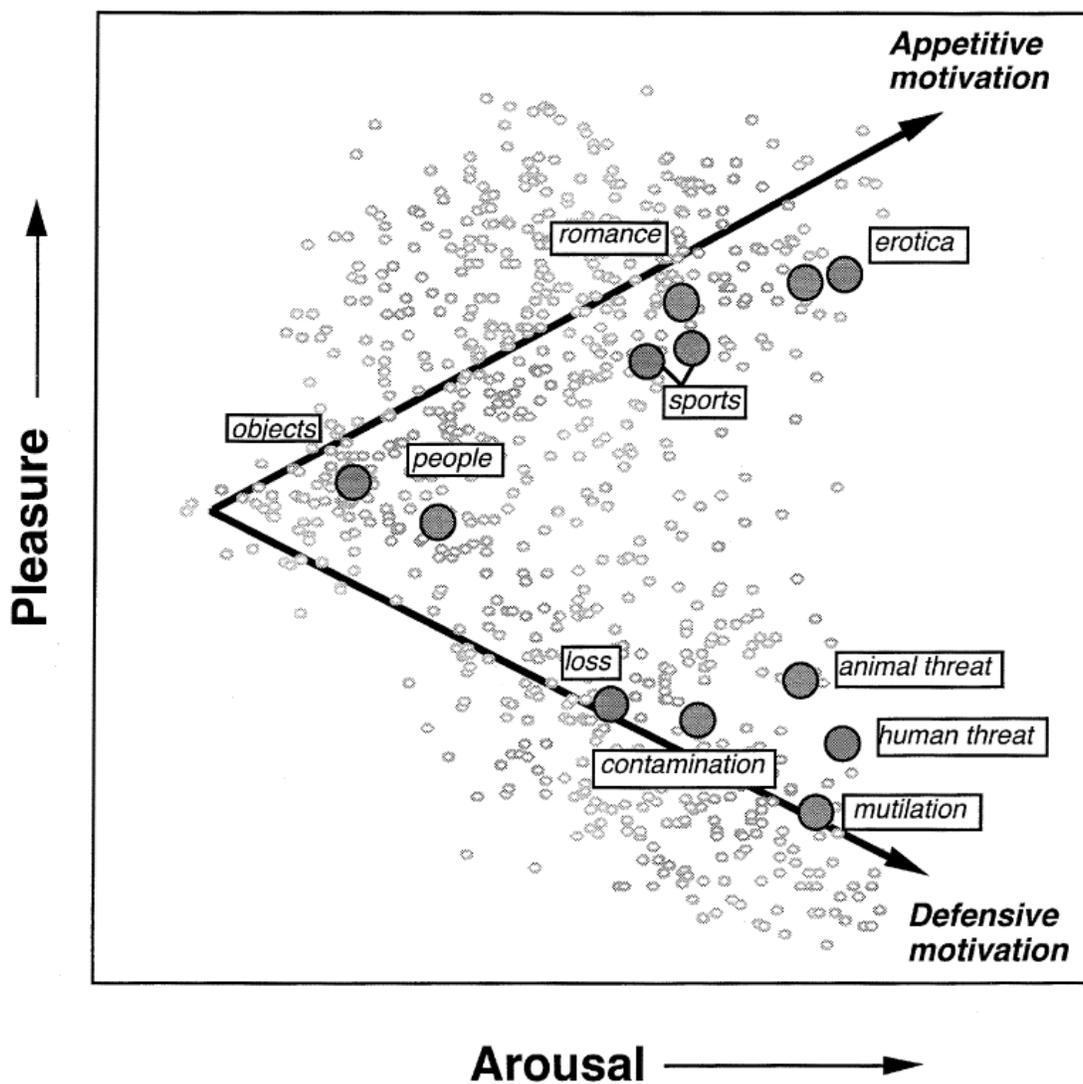
interaction). The asymmetry in the processing of positive and negative information has been described in different domains of human information processing. Several findings seem to suggest that negative information draws more attention (Pratto & John, 1991), leads to stronger physiological reactions (Ito et al., 1998), is recognized more accurately (Ortony et al., 1983), and persists more over time even when the adverse conditions have disappeared (“The Law of Hedonic Asymmetry”; Frijda, 1988).

Why may negative information have a stronger impact on cognitive processes? Several authors have suggested that this differential processing is adaptive to evolution, because negative information (e.g., a predator) could be more relevant for immediate survival than the potential long-term benefits of positive information (e.g., a food source). Negative stimuli may thereby be more potent, meaning that the threat they pose to the organism is stronger than the potential benefit of positive events. In fact, consequences of negative events are often irreversible. Since avoidance of risks should have the highest priority in the evolutionary scheme, human information processing should be shaped accordingly (for an extensive review of these effects: Cacioppo et al., 1997; Rozin & Royzman, 2001; Taylor, 1991).

Even though the negativity bias has been described in the light of its adaptive functions, it is possible to argue that a fixed negativity bias can also be maladaptive, because overlooking dangers and missing opportunities can have serious consequences in the long term. According to this view, an increasing body of evidence suggests that the significant arousing information might lead to a greater emotional response (in terms of brain response, attentional engagement, physiological reactions). In the following paragraphs, evidence that supports the negativity bias and a more general mechanism related to emotional significance will be taken into account regarding different indexes of emotional response: subjective response, brain response, attentive capture, and saccadic response.

## Subjective Evaluation of emotional stimuli

In terms of subjective responses, it is possible to investigate the evaluative process by using the evaluative categorization task. When participants were asked to evaluate their affective reactions to emotional stimuli (such as pictures of natural scenes) in terms of hedonic valence and arousal, the distribution of these reactions in a Cartesian space defined by valence and arousal ratings resulted in the affective space (Figure 1.2).

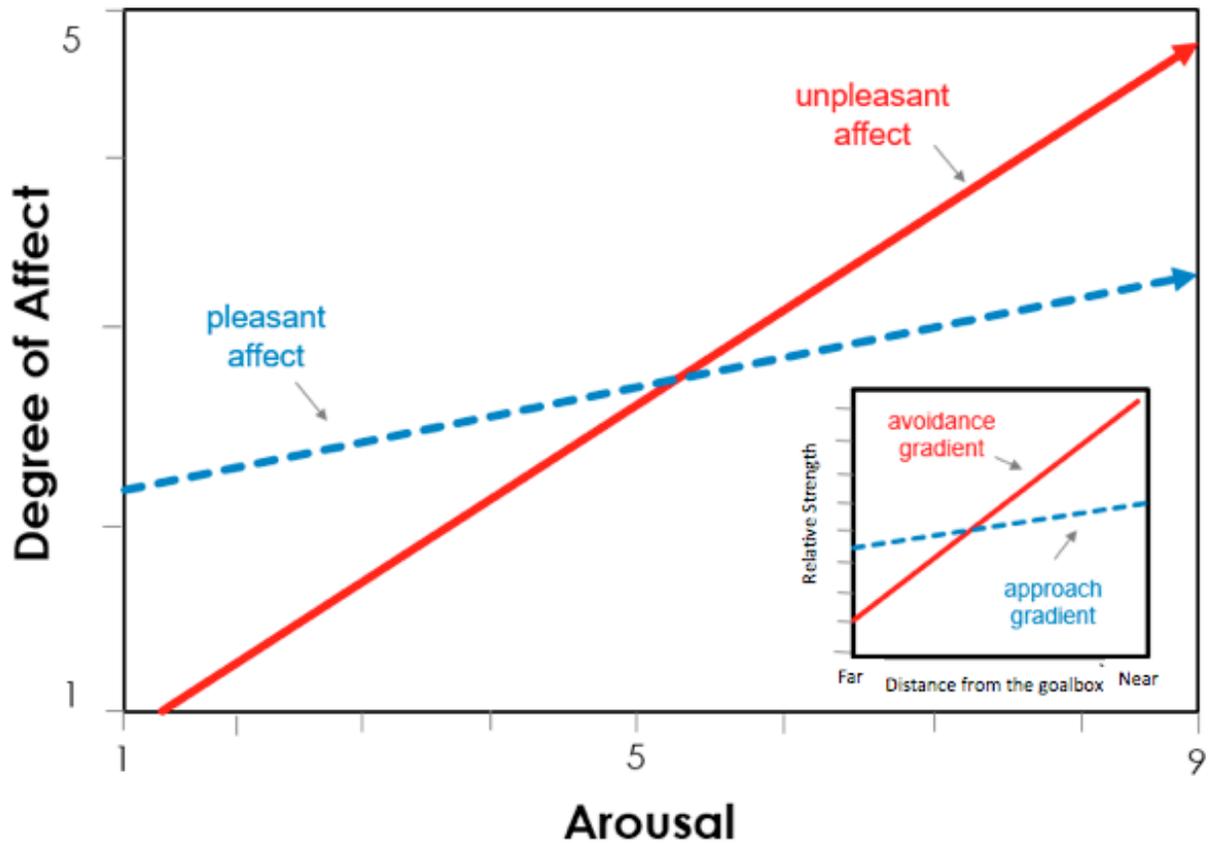


**Figure 1.2.** The two-dimensional affective space defined by mean pleasure (y-axis) and arousal (x-axis) for IAPS pictures (international Affective Picture System; Lang et al., 2001), and the location of some of the specific picture contents that are part of the IAPS data set. Vectors indicate the hypothetical appetitive and defensive motivational systems that organize affective evaluation. Adapted from Schupp et al (2004).

The shape of the affective space provides support for a fundamental organization of emotion in terms of appetitive and defensive motivation. As the affective space shows, the stimuli vary in hedonic valence: proceeding vertically in each direction from the center of the space (where neutral stimuli cluster), stimuli are rated as being progressively more pleasant or more unpleasant. Moreover, as the ratings of the hedonic valence increase in each direction, the arousal ratings tend to increase. The arrows depicted in Figure 1.2 illustrate the activation in the hypothetical underlying appetitive and aversive systems. When activation in each system is minimal, arousal is also low, suggesting only a weak tendency to approach or withdraw from the stimulus with little energy mobilization required for a minimal response. As activation in the aversive system increases, that is, when stimuli are rated as being increasingly more unpleasant, arousal also increases, presumably indexing the metabolic requirements for the behavioral response (e.g., withdraw, escape, defense). Similarly, when the activation in the appetitive system increases, arousal also increases, reflecting energy allocation to fulfill a behavioral response involved in approach or consummation.

The separate arousal gradients obtained for pleasant and unpleasant pictures in Figure 1.2 are overlaid in Figure 1.3. As shown in the inset of Figure 1.3, there is a very large overlap between the motivational gradients depicted by the subjective evaluation of arousal and valence gradients, as described by Miller in the classic studies of approach-avoidance behavior in the rat (1944, 1959). Miller found a prototypical pattern of responding in which withdrawal increased with the proximity to an aversive stimulus, whereas as a proximal appetitive stimulus was approached the response was somewhat less intense. Despite the difference between the measures that we are comparing

(approach-avoidance behavior vs. hedonic valence subjective reports; behavioral strength vs. arousal reports), reports of arousal for pleasant and unpleasant perceptual stimuli closely parallel Miller's motivational gradients.



**Figure 1.3.** The arousal slope for pleasant and unpleasant pictures closely parallel the approach and avoidance gradients based on direction and intensity of behavior originally noted by Miller (1944; inset).

Based on these data, Cacioppo and associates (Berntson, Boysen, & Cacioppo; Berntson & Cacioppo, 1994; Cacioppo et al., 1997; Ito, Cacioppo, & Lang, 1998) concluded that the positivity offset (i.e., the larger constant for positive motivation) indicates that a weak tendency for activation in the appetitive system exists when neither system is strongly active. They suggest that this tendency of approach, functioning at low levels of motivation, provides a basis for understanding the orienting and the exploratory reactions that constitute daily interactions with environmental stimuli that are neither

highly threatening nor highly appealing. The negativity bias, that is, a steeper gradient for defensive behavior, reflects a propensity to respond more strongly to aversive stimulation.

Importantly, the boomerang shape of the affective space is very similar for sets of words or sounds (Bradley & Lang, 1999a,b), instrumental music (van Oyen Witvliet & Vrana, 1996) and films (Detenber, Simons, & Bennet, 1998), suggesting a common organization for these perceptual stimuli. Moreover, to date, the steeper negative gradient has received considerable support in different perceptual modalities.

## **Brain response to emotional stimuli**

The brain response to emotional stimuli might be investigated through the use of techniques that provide information on emotional processing with high spatial resolution (functional Magnetic Resonance, fMRI) and high temporal resolution (Electroencephalogram, EEG). In the next paragraph the main evidence supporting the negativity bias and the arousal hypothesis in the central indexes of emotional responses is taken into account.

### **The negativity bias in central indexes of the emotional response**

Many studies have supported the idea that the amygdala constitutes the central structure of a modular system in the mammalian brain that has been shaped by evolution to respond to potentially fearful and threatening stimuli (e.g., Öhman and Mineka, 2000). For example, studies in patients (Adolph et al., 1994; Brooks et al., 1998; Buchel et al., 2000; Calder et al., 2001) have suggested that bilateral damage to the amygdala may impair the processing of fear expressed by the face. Moreover, similar evidence has been described in several neuroimaging studies on fearful faces (Breiter et al.,

1996; Canli et al., 2002; Morris et al., 1998; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Portas et al., 2000; Villumier, Armony, Driver & Dolan, 2001; Whalen et al., 1998) as well as on fear conditioning (Buchel & Dolan, 2000). The amygdala is also necessary in learning to associate neutral stimuli with fear responses, as consistently revealed by conditioning experiments in animals and humans (Buchel & Dolan, 2000; LeDoux, 1996). So far, a vast corpus of evidence shows that the amygdala is involved in fear processing, supporting the notion that fear-related stimuli constitute the amygdala's domain of specificity.

Since the negativity bias was originally conceptualized in studies by Cacioppo as an inherent characteristic of the motivational substrate, the authors predicted that the negativity bias might manifest at the initial evaluative categorization stage of the emotional processing (Cacioppo & Berntson, 1994; Cacioppo et al., 1997). Cacioppo and colleagues conceptualized evaluative categorization as separate from response selection and execution (or output; Cacioppo & Berntson, 1994; Berntson et al., 1993), which is a function of processes operating at either the evaluative categorization stage or the response selection-execution stage. In order to test this hypothesis, Cacioppo and associates used the event-related potentials (ERPs) as a measure of the evaluative categorization stage (Cacioppo, Crites, Berntson, & Coles, 1993). ERPs are modulations of the brain's electrical activity, which are classically analyzed in terms of components, defined as deflection of the ERP wave occurring at certain latencies. The paradigm used by Cacioppo and associates was a modification of the oddball paradigm typically used to study the P300 component of the ERP. The P300 has a maximal amplitude over central and parietal scalp areas, and manifests from approximately 300 to 900 ms following stimulus onset (Donchin, 1981). In the standard oddball paradigm, simple stimuli representing two distinct categories (e.g., low- and high-pitched tones) are presented with differing probabilities to participants. On average, the low-probability stimulus (also

called the oddball or target stimulus) evokes a larger positive potential, called the P300, as compared with the high-probability stimulus. To study evaluative processes, Cacioppo et al. (1993) presented stimuli that were either positive, negative, or neutral in valence, with stimuli from one evaluative category occurring more frequently than the others (e.g., Cacioppo et al., 1993; Crites, Cacioppo, Gardner, & Berntson, 1995). Authors referred to the frequently presented stimuli in each sequence as the context and those from the less probable categories as targets. Evaluative inconsistency between the target and context (e.g., a negative target stimulus embedded within a sequence of positive-context stimuli) results in an enhancement of a late positive potential (LPP) of the ERP, which shares many of the signature characteristics of the P300. This large amplitude in the LPP was found when adjectives describing trait characteristics were used as stimuli (Cacioppo, Crites, Gardner, & Bemtson, 1994; Crites & Cacioppo, 1996; Crites et al., 1995) or when emotional pictures were used (Ito, Larsen, Smith, & Cacioppo, 1998). Altogether, these results provide support for the hypothesis that the negativity bias in affective processing occurs as early as the initial categorization into valence classes. A recent study (Hilgard et al., 2014) tried to disentangle possible features involved in the ERP response to emotional stimuli due to the lack of the negativity bias in a series of systematic studies performed in the past fifteen years by Lang, Bradley, and associates (discussed later in this paragraph). Hilgard and colleagues (2014) sought to clarify the nature of the negativity bias in affective picture processing by testing the extent to which the LPP elicited by pleasant and unpleasant images is influenced by both bottom-up and top-down motivational significance, represented here by the contents of pleasant images and variation in picture viewing paradigms, respectively. The findings were largely consistent with the main hypothesis that a negativity bias is more likely to emerge within the context of an oddball paradigm, in which valenced targets are relatively infrequent and unpredictable and (in the paradigm used here) a behavioral response is required, than in blocked or

random viewing paradigms, and when the specific contents of unpleasant and pleasant images are not equated for relevance to biological imperatives.

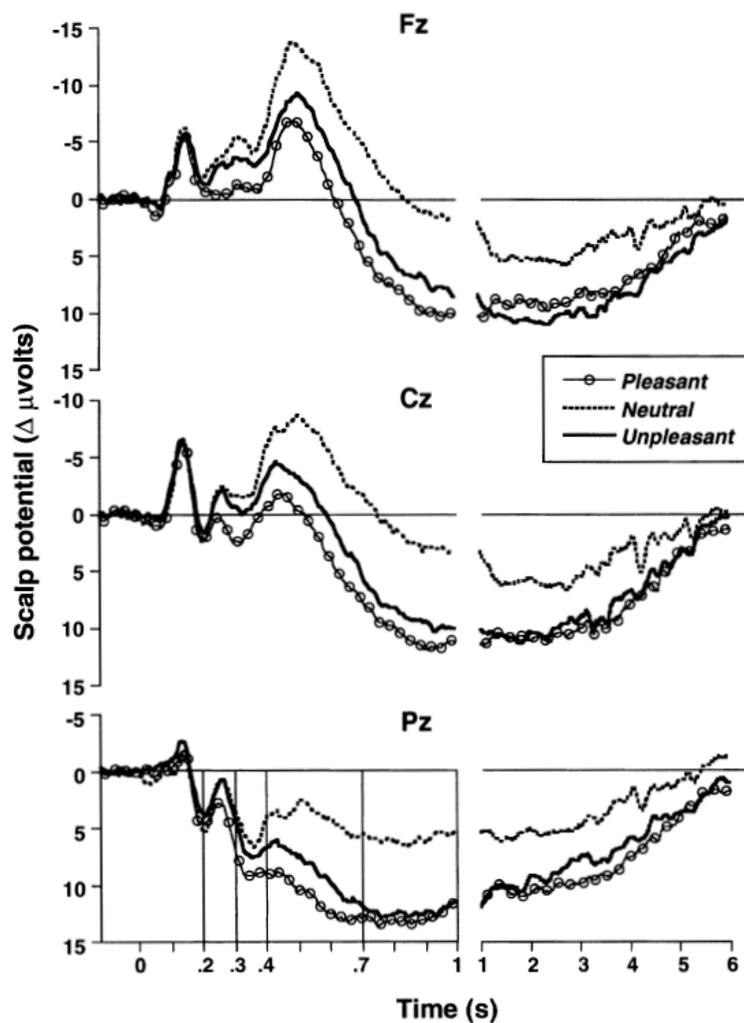
### **Emotional significance and brain response.**

Even though the amygdala has been described as a highly specific region in the processing of negative threatening information, an increasing number of studies has suggested that this region reflects the sensitivity to the motivational relevance of visual scenes (e.g., Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005; Sabatinelli, Frank, Wagner, Dhamala, Adhikari, Li, 2014).

Similarly, even though the negativity bias in terms of LPP has received partial support, a systematic series of studies on the functional meaning of the LPP emotional modulation suggests that the LPP does not differentiate appetitive and defensive content that is matched for arousal ratings (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp, Cuthbert, Bradley, Hillman, Hamm, & Lang, 2004; Schupp, Flaisch, Stockburger, & Junghofer, 2006).

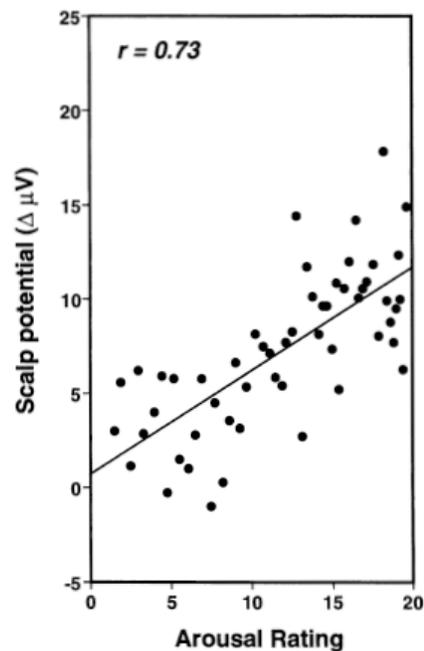
The first important study that investigated the emotional modulation of the late positive potential was conducted by Radilova (1982). Even with a limited number of participants (ten) and with just one parietal electrode, this first study clearly showed that high arousing contents might evoke a larger positive response (defined by Radilova as “late P3 wave”) compared to less arousing contents, suggesting that the “P3 wave of visual evoked response reflects, in addition to the cognitive aspects, the emotional impact of the stimuli administered to the subjects”. Following this study, an increasing body of literature focused on the emotional modulation of the late positive potential with results suggesting that this component might vary as a function of the emotional value of the stimuli. Johnston, Miller, and Burleson (1986) provided an important contribution to this literature, extending the results that suggested a key role of the stimulus utility in determining the P3 amplitude (Ruchkin

& Sutton, 1978; Johnston, 1979; Johnson & Donchin, 1985) to the idea that utility might be redefined in terms of emotional value. The past 20 years of systematic research have suggested that emotional significance is the key factor that determines LPP modulation. Cuthbert and colleagues (Cuthbert et al., 2000) further contributed to the literature with their suggestion that a larger positivity was induced by contents that prompted a larger increase in the autonomic response and reported a greater affective arousal (erotic scenes and scenes of violence), suggesting that the LPP response might be modulated by emotional arousal rather than by valence (Figure 1.6 and Figure 1.7).



**Figure 1.6.** Stimulus synchronized grand average ERP waveform for Fz, Cz, and Pz electrodes during viewing of affective pictures, separately for each valence category (pleasant, neutral, and unpleasant). The panel on the left illustrates the picture onset potentials on a fine time scale, and the right-hand panel shows the subsequent 5 s slow potential change.

These results were further extended by the same research group in a later study (Schupp et al., 2004). Schupp and colleagues used pictures of 12 different contents and showed that the LPP response is modulated by the emotional significance of the scene and that a larger late positive potential is induced by erotic scenes and scenes of threat and mutilations, suggesting heightened motivational and attentional engagement to contents that are presumed to engage the appetitive and defensive motivational systems more strongly.



**Figure 1.7.** Covariation between the judged arousal and average midline EEG in the activity in the 700-100 ms after picture onset. Adapted from Cuthbert et al., 2000.

Several subsequent studies confirmed that the affective modulation of the LPP seems to be greater when viewing high arousing, compared to low arousing, pictures and does not differentiate appetitive and aversive contents (Palomba, Angrilli, Mini, 1997; Schupp et al., 2000; 2006)

A series of studies has demonstrated that these emotional cues also persist in modulating the LPP even under perceptually challenging conditions in which the stimuli are relatively degraded with a very small visual angle ( $3^\circ \times 2^\circ$ ; De Cesarei & Codispoti, 2006; 2011a), and very brief exposure duration (25 ms; Codispoti, Mazzetti, & Bradley, 2009; Ferrari, Codispoti, Cardinale, & Bradley, 2008; Codispoti, De Cesarei, Ferrari, 2012).

Moreover, a series of studies demonstrated that the affective modulation of the LPP is not due to bottom-up perceptual factors, picture color, complexity, or spatial frequencies (Codispoti et al., 2006; De Cesarei & Codispoti, 2011b; Ferrari, Bradley, Codispoti, & Lang, 2010), relying, rather, on the recognition of the emotional content of the stimuli (Codispoti et al., 2009).

Another important series of studies investigated whether the LPP emotional modulation might represent a mandatory process. In fact, if the discrimination of affective stimuli is an obligatory process, the emotional modulation of the LPP should persist despite multiple repetitions. According to this hypothesis, several studies showed that the emotional modulation of the LPP persists even after massive repetition, with emotional pictures that continue to elicit a larger late positive potential than neutral ones (Codispoti, Ferrari, & Bradley, 2006, 2007; Ferrari et al., 2011; 2015;). However, the studies that examined the effects of stimulus repetition on the LPP mainly used a free-viewing task, in which emotional stimuli were expected. In order to investigate the LPP affective modulation while participants were actively engaged in an unrelated task, Codispoti and colleagues (Codispoti, De Cesarei, Biondi, Ferrari, 2016) showed that the LPP amplitude continued to be enhanced for emotional compared to neutral distractors even after several repetitions and the presence of a

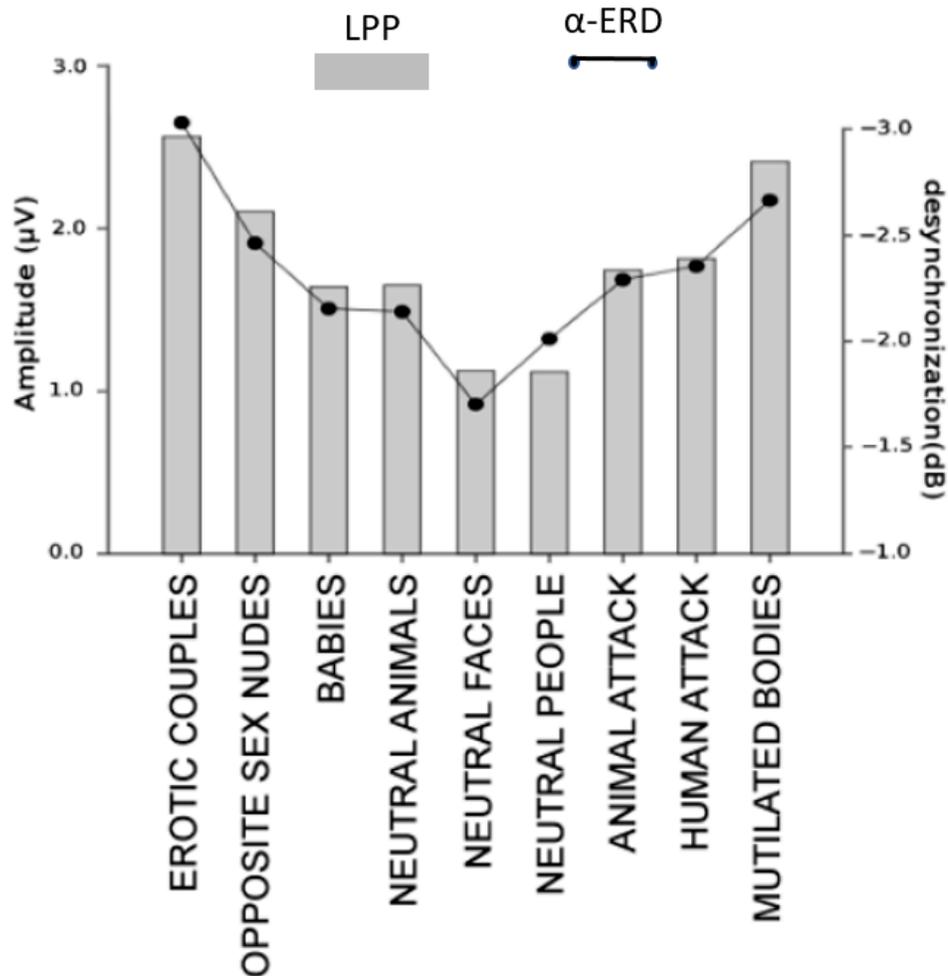
concurrent task, while the behavioral interference induced by the emotional distractors disappeared after a few repetitions. The results of this study suggested that the evaluation of emotional stimuli is mandatory and continues to engage the appetitive and defensive systems even after massive repetition, as suggested by the LPP emotional modulation, while attentional engagement is no longer required, as suggested by the behavioral interference data.

Taken together, these results suggest that the affective modulation of the LPP reflects both the engagement of attentional resources by emotional stimuli and the activation of motivational systems (Ferrari, Bradley, Codispoti, & Lang, 2011; Lang, Bradley, & Cuthbert, 1997; Schupp et al., 2006; Weinberg & Hajcak, 2010).

The EEG response might be characterized not only in the time domain with the event-related potentials, but also in the time frequency domain with EEG oscillations. The Alpha wave is a rhythmic oscillation of EEG frequency ranging from 8 to 12Hz. In tasks requiring categorization of task-relevant events, targets result in a more pronounced desynchronization of the EEG alpha band compared to the non-target stimuli (Klimesch, Doppelmayr, Russeger, Pachiner, & Schwaiger, 1998).

Recent studies (De Cesarei & Codispoti, 2011a; Ferrari, Bradley, Codispoti, & Lang, 2015) have investigated the effects of natural scenes, varying in emotional picture content and size, on  $\alpha$ -ERD and LPP. The authors showed a clear relationship between affective modulation of both measures, with the pattern of affective modulation of these two brain measures modulated by emotional content as shown in Figure 1.7. Additionally, the results of a study by De Cesarei and Codispoti (2011) suggest that, during affective picture viewing, these two brain responses similarly reflect the engagement of motivational systems to facilitate perception. Importantly, this study provides further support to the hypothesis that the evaluative process, indexed by the LPP, is related to emotional significance and

does not differentiate positivity and negativity. Moreover, the LPP results were further extended by the Alpha-ERD response, that showed a similar emotional modulation of the LPP, highlighting the role of arousal in the emotional response.



**Figure 1.7.** The effects of picture category on the LPP (bars) and Alpha-ERD (line and dots). Adapted from De Cesarei and Codispoti (2011).

## Attentional engagement to emotional stimuli.

Do negative stimuli draw more on attentional resources than positive ones? This important question has been investigated in studies that used emotional stimuli as distractors. In the next paragraph

evidence that supports the negativity bias or the salience hypothesis regarding the attentional engagement to emotional stimuli is described.

### **The negativity bias in attentional engagement.**

As previously discussed, the negativity bias seems to be a pervasive phenomenon in many cognitive functions. In terms of attentional engagement, the central prediction of the negativity bias hypothesis is that our attentional system is tuned to prioritize negative (or, more specifically, threatening) information over neutral or positive information. Öhman and Mineka (2001) proposed a threat-detector module that provides preferential sensitivity to cues that signaled threat in our evolutionary past (e.g., predators), presumably via an amygdala-mediated mechanism. This sensitivity is assumed to have evolved due to the fact that the detection of danger has a higher survival value compared to the detection of neutral or even positive cues. Negative stimuli are thereby more potent, meaning that they are more threatening to the organism than positive events are beneficial. In line with this assumption, negative information has often been found to weigh more heavily than neutral and positive information on the engaging and/or holding of attention (e.g., Armony & Dolan, 2002; Carlson et al., 2012; Carretié, Mercado, Tapia, & Hinojosa, 2001; Hajcak & Olvet, 2008; Öhman, Flykt, & Esteves, 2001; Öhman, Soares, Juth, Lindström, & Esteves, 2012; Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Pratto & John, 1991; Smith, Cacioppo, Larsen, & Chartrand, 2003). However, studies investigating preferential attention to negative stimuli often employed only the negative valence category without any comparison with positive valence (e.g., Armony & Dolan, 2002; Carlson et al., 2012; Öhman et al., 2001). Moreover, it is suggested that the negativity bias can depend heavily on the paradigm and stimulus material used (e.g., Hahn & Gronlund, 2007; Hilgard, Weinberg, Hajcak Proudfit, & Bartholow, 2014; Weinberg & Hajcak, 2010), the experimental situation adopted (e.g.,

Smith et al., 2006), and on personal factors (e.g., high anxiety: Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), thereby undermining the view of an “obligatory” and unitary negativity bias.

### **Emotional significance and attentional engagement.**

Motivationally relevant stimuli (i.e., those that strongly activate either the appetitive or defensive system) engage attentional processes, which facilitate perceptual encoding and recognition in sensory systems (Beaver, Mogg, & Bradley, 2005; Derryberry & Tucker, 1994; Fox et al., 2000; Fox, Russo, & Dutton, 2002; Lang, Bradley, & Cuthbert, 1990, 1997; Mogg & Bradley, 1999; Phelps, Ling, & Carrasco, 2006; Vuilleumier & Driver, 2007). A greater attention allocation to emotional pictures compared to neutral ones has been suggested by a number of physiological and behavioral measures. For example, in a series of studies Margaret Bradley and collaborators (Bradley, Cuthbert, & Lang, 1996a, 1999a) explored attentional processes during picture perception by delivering a tone probe after picture onset and asking participants to respond as fast as possible to the tone while ignoring the background pictures. Participants showed longer reaction times when emotional pictures were presented in the background compared to neutral pictures. Interference effects caused by task-unrelated emotional pictures have been observed during a variety of visual and acoustic tasks, suggesting that motivationally relevant stimuli draw more on attentional resources, leaving them less available for task processing (Bradley et al., 1996b, 1999; Calvo & Nummenmaa, 2007; Okon-Singer, Tzelgov, & Henik, 2007; Pereira et al., 2006). Although some studies have suggested that unpleasant stimuli capture greater attention than pleasant stimuli do (Hartikainen, Ogawa, & Knight, 2000; Ohman, Lundqvist, & Esteves, 2001; Pratto & John, 1991), when pleasant and unpleasant stimuli were equated in terms of arousal ratings, no difference as a function of valence was found, and highly arousing

picture contents (pleasant and unpleasant) captured greater attentional resources than low arousing stimuli (Blair et al., 2007; Bradley et al., 1999; Bradley, Drobles, & Lang, 1996; Nummenmaa, Hyona, & Calvo, 2006; Schimmack, 2005; Verbruggen & De Houwer, 2007). A large amount of literature has ascribed the effects of emotional stimuli on subjective ratings and cognition to their intrinsic relevance, related to the evolutionary significance of appetitive or threatening stimuli.

### **Saccadic behavior toward stimuli outside the focus of attention.**

The evaluation process requires the dynamic assessment of many positive and negative stimuli within the organism's external and internal environments. In order to evaluate the stimuli in our environment, we have to continuously scan the world around us to look for threat and potential rewards. One of the most important aspects of the primate visual system is that in order to examine our environment, we have to make fast ballistic eye movements called saccades. Saccades are necessary to quickly bring the fovea, the part of the retina with the highest acuity, to different parts of the visual scene. Scanning visual environments is an activity that is ubiquitous to all aspects of our everyday life.

One key question is whether the emotional significance of stimuli presented outside the focus of attention, that is in parafoveal vision (usually around 5° away from fixation), might attract attention and facilitate identification of scenes in the visual periphery, compared to neutral stimuli. Several predictions might be proposed in the modulatory pattern of the saccadic response as a function of hedonic valence or emotional significance. In the next paragraph the evidence supporting the negativity bias and the salience hypothesis in saccadic behavior are discussed.

### **Saccadic Behavior and Hedonic Valence: Approach-Avoidance vs. Negativity Bias**

The primary role of attention consists in selecting behaviorally relevant sensory input, such as stimuli that signal danger or rewards. The influential Premotor Theory of Attention (Rizzolatti, Riggio, Descola, Umiltà, 1987) proposed that spatial attention is the consequence of the activation of the motor system, and shifts of attention are carried out by planning goal-directed actions. In particular, the oculo-motor system could have an important role in selective spatial attention (Rizzolatti, Riggio, & Sheliga, 1994). Because the behavioral repertoire of human beings and animals has evolved during the course of evolution from basic approach-avoidance tendencies (e.g., Schneirla, 1959), one possibility is that saccadic behavior might be modulated by approach-avoidance tendencies (where pleasant stimuli have a positive value and elicit approach, and unpleasant stimuli have a negative value and elicit avoidance). This hypothesis has been supported by a recent study on gaze behavior, with delayed saccades toward negative stimuli and away from positive stimuli (Deuter, Shilling, Huehl, Blumenthal, & Schachinger, 2013).

The approach-avoidance hypothesis is not the only one that leads to a saccadic response modulated by the emotional valence of the stimuli. Presumably, if we consider the adaptive function of positive and negative stimuli, it should be more important to detect unpleasant stimuli than pleasant ones, as missing a threat-related cue seems more costly than missing a reward. In order to assess the extent to which pleasant and unpleasant visual stimuli presented extrafoveally capture attention and impact eye movement control, McSorely and van Reekum (2013) examined deviations in saccade metrics in the presence of emotional image distractors that were close to a non-emotional target. By also manipulating the saccade latency in order to test when the emotional distractor has its biggest impact on oculomotor control, the authors found that the saccade landing position was pulled toward

unpleasant distractors, and that this pull was due to the quick saccade responses. Overall, these findings support a negativity bias account.

### **Emotional significance and saccadic behavior.**

Many studies have investigated attention to emotional scenes in extrafoveal vision (generally,  $\geq 5^\circ$ ). Eye movement research has found that emotional scenes selectively attract overt attention. When an emotional and a neutral scene are presented simultaneously, the first fixation is more likely to be directed to the emotional image (Alpers, 2008; Calvo & Lang, 2005; Calvo, Nummenmaa & Hyönä, 2008; but see Acunzo & Henderson, 2011), and saccade latencies can be shorter for emotional scenes (Calvo, Nummenmaa & Hyönä, 2008). This reveals selective orienting, and occurs even when viewers are instructed to look first at the neutral picture (Nummenmaa, Hyönä & Calvo, 2006). Furthermore, when viewers are asked to perform a saccade to an exogenous (non-emotional) cue, trajectories deviate towards the emotional scene (McSorley & van Reekum, 2013), and latencies are longer when the image opposite to the instructed direction is emotional (Nummenmaa, Hyönä & Calvo, 2009). Similarly, anti-saccade responses show more errors toward emotional than neutral images (Kissler & Keil, 2008). Altogether, this suggests that emotional significance is perceived even when the stimulus is still outside foveal vision, allowing for the fast detection of relevant stimuli.

## **Research Overview**

The present work mainly focuses on the functional differences in the evaluation of pleasant and unpleasant natural scenes in order to test whether negative information weighs more heavily than positive information. In brief, the first line of inquiry (Experiments 1-2) investigates the functional

differences in the appetitive and defensive gradients when they are described by subjective evaluation of the affective states, and when the same gradients are described by the physiological response to emotional stimuli that vary in arousal level. Starting from the assumption that the negativity bias might arise when a negative highly-threatening stimulus appears near a positive stimulus or in a pleasant context, the second line of inquiry (Experiments 3-4) targets the question of whether a negativity bias might occur in the attentive capture regarding task-irrelevant emotional pictures when a negative stimulus appears near a positive one or when unpleasant stimuli are primed by pleasant ones. The third line of inquiry (Experiments 5-6) will investigate whether the saccadic approach behavior might be modulated by the emotional content of the starting and ending stimuli, in order to explore whether negative stimuli show an advantage, in terms of response latency, compared to positive and neutral stimuli. Table 1 shows an overview of the experiments, with the measures used and the main questions to be explored.

Experiment	Measures	Research Questions
1-2	Self-reported measure of valence and arousal, Skin Conductance Changes, Late Positive Potential (LPP), Alpha-Desynchronization ( $\alpha$ -ERD)	Are there functional differences in the evaluative processes of appetitive and aversive stimuli? In particular, are they characterized by different subjective and physiological patterns in response to stimuli of increasing relevance?
3-4	Behavioral Interference in an unrelated task	Is the evaluative process affected by the simultaneous activation of both motivational systems? How do appetitive information and aversive information interact when they both compete for attentional resources?
5-6	Saccadic Latency (reaction times), Saccadic Accuracy	How does valence interact with the saccadic-approach behavior? Does valence interact with the disengagement from emotional stimuli?

**Table 1.1.** Overview of the experiment, with the main questions and the measures used to answer them.

# Chapter 2

## The Motivational Gradients

Survival depends on the ability to evaluate and detect potential threat and rewards, and adapt one's behavior accordingly. As studies on animals and human beings have suggested, the behavioral response is organized based on stimulus significance, and the response pattern is mediated by the different engagement of the motivational systems. Miller's studies on conflict behavior (1944, 1959) suggested that stimulus significance might be defined by the distance between the organism and the encounter stimulus. In his seminal studies, Miller (1944, 1959) described distinct gradients of approach and avoidance when the animal is facing a stimulus that has positive or negative significance. Specifically, these studies showed that animal behavior varies as a function of the distance and the valence of the stimulus, and described different slopes in response to appetitive and aversive stimuli. The strength of the behavioral response (approaching appetitive cues and withdrawing from threatening ones) has been shown to be modulated by stimulus distance, with a stronger response for near compared to far away cues. Moreover, the gradient of approach/withdrawal as a function of distance is steeper for unpleasant compared to pleasant stimuli. Similarly, studies on human beings have suggested that the emotional response is larger for nearer stimuli: a study that compared the reaction of snake-phobic participants to snakes presented at various distances (Taghtesoonian & Frost, 1982) showed a linear increase in autonomic responses and self-reported fear as a function of distance.

The emotional significance of a stimulus might be defined by contextual cues, such as the distance between the organism and the stimulus, and by the biological relevance of the stimuli (Bradley, 2000; Schupp et al., 2004).

Interestingly, similar gradients to those originally described by Miller were found in self-report ratings of valence and arousal (Ito, Cacioppo, & Lang, 1998), suggesting that the “proximity” dimension may be related to the more general “arousal” construct (Lang et al., 1997). Based on these results and the parallel data from Miller’s studies on animal behavior, Cacioppo described the functional differences in the appetitive and defensive gradients in terms of positivity offset and negativity bias. In order to investigate these functional differences in the appetitive and defensive motivational systems, researchers have systematically investigated the emotional modulation of the Late Positive Potential (LPP) as an index of motivational engagement. Although some studies have suggested that a larger LPP is prompted by high-arousing negative compared to positive and neutral stimuli (Ito et al., 1998; but see also Hilgard, Weinberg, Hajcak Proudfit, & Bartolow, 2014), when pleasant and unpleasant stimuli were equated in terms of arousal ratings no difference as a function of valence was found, and highly arousing picture contents (pleasant and unpleasant) elicited a larger LPP compared to neutral contents (Ferrari, Bradley, Codispoti, & Lang, 2011; Lang, Bradley, & Cuthbert, 1997; Schupp et al., 2006; Weinberg & Hajcak, 2010). Importantly, the LPP emotional modulation does not suggest differences in response to pleasant and unpleasant stimuli even when bottom-up factors are considered (Codispoti et al., 2009, 2012; De Cesarei & Codispoti, 2011a, 2011b).

However, a large part of the literature investigating the affective modulation of the LPP has mostly focused on the comparison between high-arousing emotional (erotic couples and mutilations) with neutral contents, precluding the possibility of comparing the differences in motivational gradients. To date, a few studies have used pictures varying in emotional contents, but the limited number of

stimuli used in these experiments did not allow for a systematic comparison between the gradients. For example, Cuthbert and colleagues used 18 positive, 18 neutral, and 18 negative stimuli of various contents (Cuthbert et al., 2000), while Schupp and colleagues used 60 pictures in 12 different categories, with 5 pictures per category (Schupp et al., 2004). Even though these studies found an important linear relationship between the arousal judgments and the LPP amplitude (Cuthbert et al., 2000), suggesting a progressive engagement of the motivational systems as a function of the increasing emotional significance, the methodological limitation represented a constraint in the investigation of the motivational gradients. Whether the motivational systems differentiate appetitive and aversive stimuli as a function of emotional significance (arousal) is still an open question. Moreover, previous studies operationalized the emotional significance in terms of subjective arousal, and no direct comparison has yet been made between the emotional significance defined by the subjective response and by the autonomic response (skin conductance changes).

Our goal in Experiments 1 and 2 was to investigate the functional differences between the appetitive and defensive motivational gradients described by the behavioral (self-evaluation), autonomic (skin conductance changes), and neural (LPP and Alpha-desynchronization) indexes of the emotional response. To this purpose, we collected a large sample of stimuli (1200 pictures) that varied within the categories of pleasant, neutral, and unpleasant contents. These stimuli were selected based on previous studies investigating central and peripheral changes in response to emotional stimuli of different contents (Bradley, Codispoti, Cuthbert, & Lang, 2000; De Cesarei & Codispoti, 2008, 2011; Schupp et al., 2004). The large sample of stimuli allowed us to create a continuum of arousal by using self-evaluation of the affective state induced by the emotional pictures. Specifically, based on the subjective evaluation of arousal (Experiment 1), stimuli were dichotomized according to whether they evoked predominantly positive or negative reactions according to the median value of Valence

Ratings. The distribution of the whole sample of stimuli was split, thus, into two sides, one appetitive and one aversive. Subsequently, the stimuli on each side were ranked into 10 groups according to their Arousal Ratings. Once the gradients were defined, we tested the differences between them by using different measures of the emotional response (self-report, skin conductance, LPP, Alpha-ERD) according to a comparison of correlations from dependent samples (Steiger, 1980). If motivational systems differentiate positivity and negativity, we would expect to find steeper negative gradients not only from the self-evaluations (see Ito et al., 1998), but also according to the autonomic and neural responses.

## **Experiment 1: Evaluative Categorization of Emotional Stimuli**

Experiment 1 was designed to investigate the functional differences in the motivational gradients defined by the participants' subjective evaluation and by a physiological measure of sympathetic activation, skin conductance changes. Several studies have suggested that the amount of skin conductance activity increases as the rated arousal of an emotional picture increases, regardless of its emotional valence (e.g., Bradley, 2000; Bradley, Codispoti, Cuthbert, & Lang, 2001).

In Experiment 1 participants were engaged in an evaluative task in which they had to evaluate their affective reactions to natural scenes in terms of valence and arousal. Previous studies suggested that a steeper negative gradient is described by subjective evaluation of emotional stimuli like pictures (Ito, Cacioppo, & Lang, 1998), words (Bradley & Lang, 1999a), sounds (Bradley & Lang, 1999b), instrumental music (van Oyen Witvliet & Vrana, 1996) and films (Detenber, Simons, & Bennet, 1998), suggesting a common organization for these perceptual stimuli. In line with these results, we would

expect the motivational gradients described by the subjective responses to show a steeper negative gradient. However, if negative stimuli have a greater adaptive value, we would expect the negative stimuli to be evaluated as being overall more arousing than positive stimuli, even when a similar slope was generated. Because several studies suggest that skin conductance varies as a function of arousal ratings, we could expect a similar pattern in the motivational gradients from the skin conductance and subjective evaluations.

## **METHOD**

### **Participants**

Sixty participants (30 females) took part in this study ( $M=25.46$ ,  $SD= 3.7$ ). Subjects were free from psychiatric or neurological disease or related past history, as indicated by self-report.

### **Stimuli and Equipment**

Images were selected from various sources including the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and Internet. Based on the arousal ratings and physiological data from previous studies which investigated affective reactions to comparable picture content (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley & Lang, 2007), twelve picture categories were selected (each  $N = 100$ ): erotic couples, romance, babies, natural places, moving people (e.g., people walking in the city), static people indoors, static people outdoors, neutral urban scenes (e.g., pictures of buildings or streets), urban decay, illness, human attack, and mutilated bodies, for a total of 1200 pictures. Each picture was adjusted to an average luminance and contrast value and resized to  $1024 \times 768$  pixels.

The whole set of stimuli was divided into ten subsets (120 pictures each), each containing 10 pictures from every content category. The presentation sequences of every subset were built with the constraints that no more than three consecutive images with the same valence would be presented, and no consecutive images with the same content would appear.

Pictures were presented using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) on a 19" monitor.

### **Procedure**

On arrival, participants were introduced to the laboratory and warned about the arousing content of some images. After having signed an informed consent form, the participant was accompanied to the experimental room and the electrodes were placed. The experimenter then read the instructions aloud and the experiment began.

Each participant viewed one of the subsets (120 pictures). During each trial, a picture was presented for 4 seconds in the center of the screen (See Figure 2.1). After a blank screen lasting 4 seconds the visual rating scales of valence and arousal were presented. After the ratings, a blank interval lasting between 12 and 14 seconds was presented (ITI). During the inter-trial interval, a fixation cross was displayed in the center of the screen.

### **Physiological response measurement**

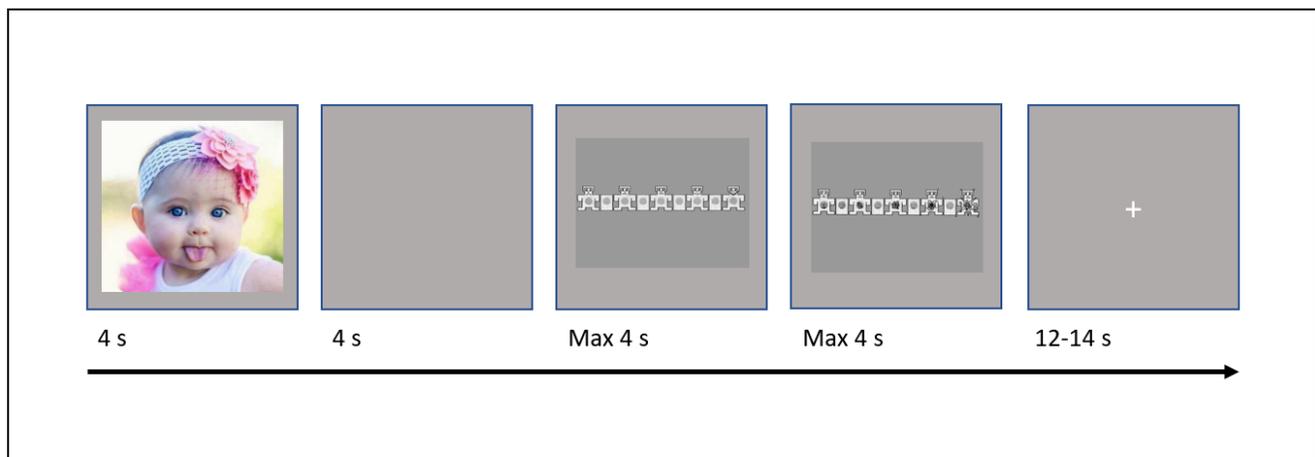
The skin conductance response was recorded during the experiment. Skin conductance was recorded using 7-mm Ag/Cl electrodes filled with the recommended 0.05 m NaCl Unibase Paste, which were placed on the hypothenar eminence of the left palm. The signal was acquired using a Coulbourn V71-

23 module which was calibrated before each session to detect activity in the range of 0-25  $\mu\text{S}$ , and sampled to 20 Hz.

The data were analyzed in half-second bins, and transformed into change scores by subtracting activity in the one-second interval preceding picture onset. Skin conductance response was scored as the maximum change occurring between 1 and 4 seconds from picture onset. SCR data were normalized using a logarithmic function ( $\log [\text{SCR} + 1]$ ) (Venables & Christie, 1980).

### Ratings

After each picture, participants were requested to rate valence and arousal of their current emotional state. Ratings were collected using the Self-Assessment Manikin (SAM; Lang, 1980), a visual rating scale (9 levels) that allows participants to rate pleasantness and intensity of the emotional state experienced.



**Figure 2.1.** Each trial started with the presentation of a picture for 4s. After a blank (4s), the participant was engaged in the subjective evaluation of pleasure and arousal; each evaluation appeared on the screen for up to 4 seconds and disappeared after the participant's evaluation. The trials ended with an intertrial interval of 12-14 seconds.

### Data analysis

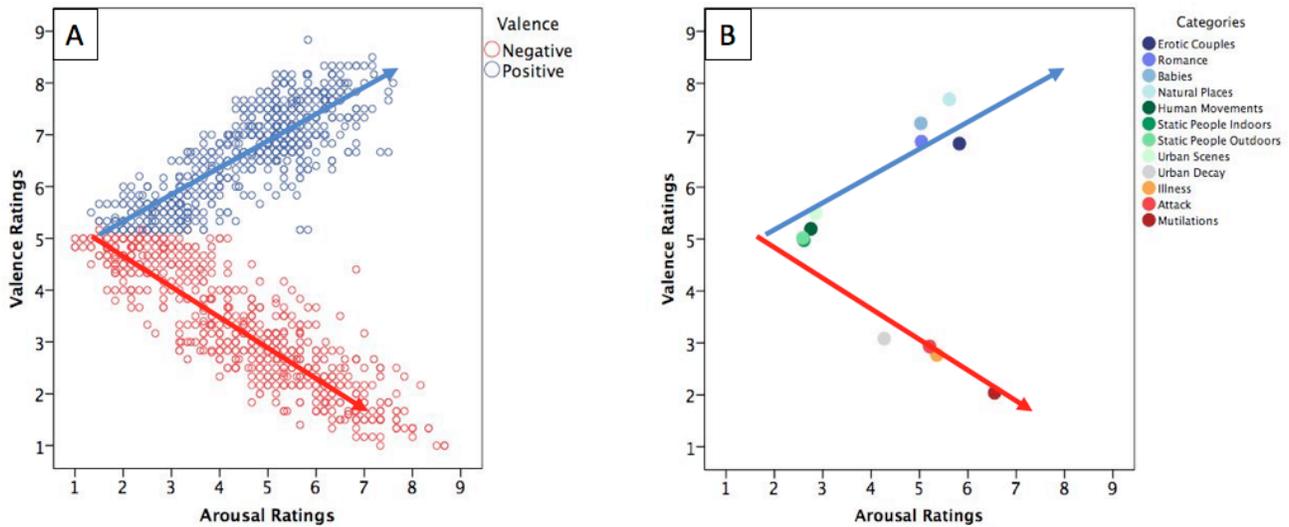
The main analysis was performed on the entire sample of the stimuli. The initial step of the data analysis was performed in order to define the motivational gradients. First, the stimuli were dichotomized based on whether they evoked predominantly positive or negative reactions according to the median value of the valence ratings. Second, 10 ranks were created within the groups of appetitive and aversive valence ratings by using the arousal evaluations. Once the gradients were defined, we tested the differences between the gradients according to a comparison of correlations from dependent samples (Steiger, 1980).

## **RESULTS**

### **Affective Space**

The distribution of the subjective ratings of valence and arousal takes on a boomerang shape with two arms that reach toward the high arousal quadrants (Figure 2.2 A). These distributions reflect the motivational foundation of affective judgments.

The regression lines based on the correlation between reports of valence and arousal, separately calculated for pleasant and unpleasant stimuli based on the median value of the valence ratings, are here considered to be motivational vectors that indicate the degree to which stimuli engage the brain's motive appetitive and defensive systems. The upper arm of the boomerang indexes appetitive motivation, in which stimuli judged to be pleasurable range in rated arousal from relatively calm to highly arousing; the lower arm indexes defensive motivation, in which unpleasant stimuli range from calm to highly arousing. A similar representation can be seen in Figure 2.2 B, in which the mean arousal and valence ratings are reported for each category.



**Figure 2.2.** (A). The boomerang shape as described by the affective space defined by mean pleasure (y-axis) and arousal (x-axis) for the pictures used in Experiment 1 (B). The location of the specific picture contents used in this experiment based on the mean pleasure and arousal ratings for the exemplars in each picture content. (A,B). Vectors indicate the hypothetical appetitive and defensive motivational systems that organize affective evaluations.

### Motivational gradients

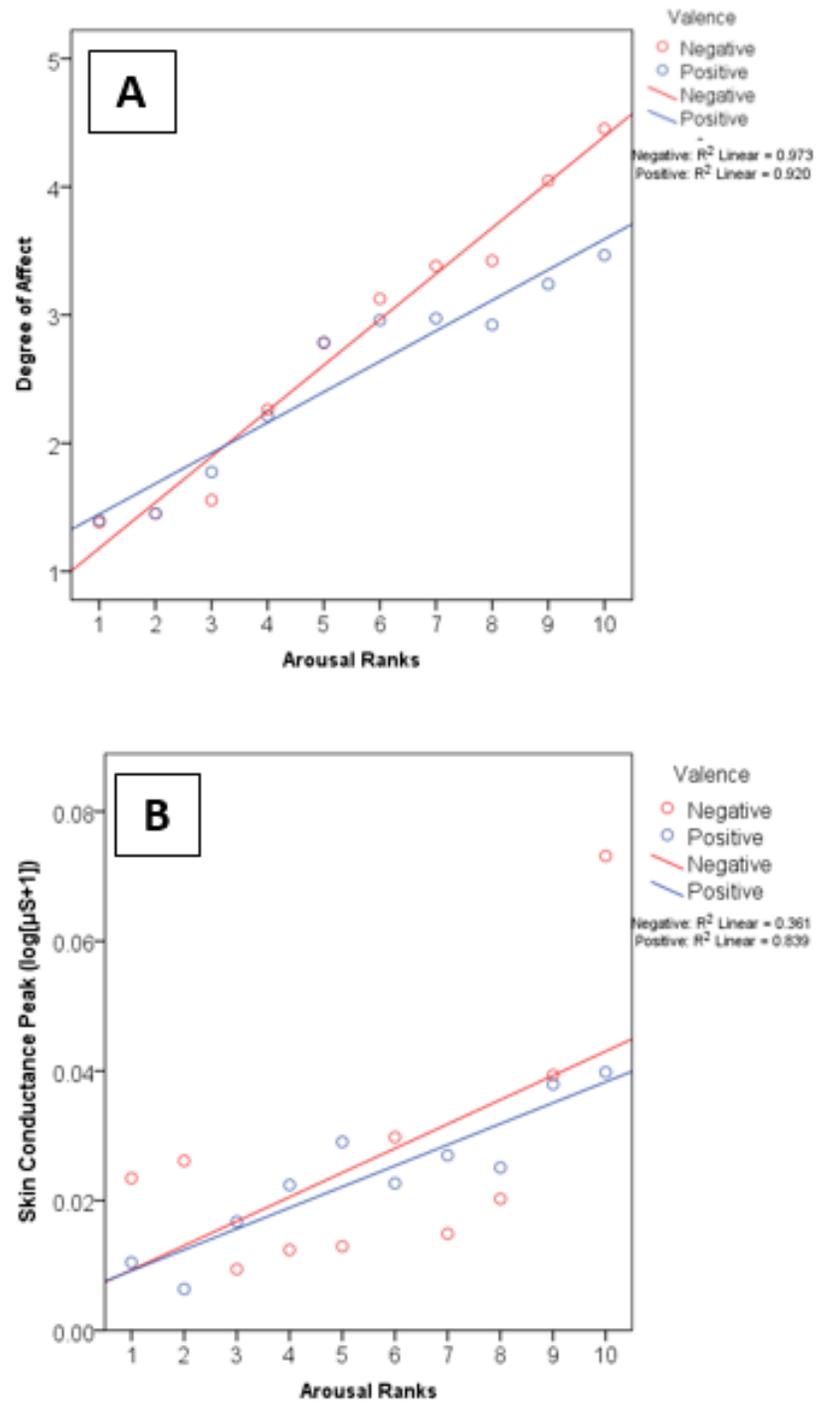
*Subjective Evaluations.* Figure 2.3A shows the relationship between valence and arousal ratings. The subjective valence ratings of each picture were transformed into the variable defined “Degree of Affect” according to the following formula:

$$\text{Degree of Affect: Absolute Value [ (Valence Rating – Valence median) +1 ]}$$

The trend of the appetitive and the aversive gradients were perfectly described by a linear fit in the defensive gradient,  $R^2 = .973$ , and in the appetitive gradient,  $R^2 = .92$ . A significant correlation between the negative valence and the arousal ranks was detected,  $r = .998$ ,  $p < .0001$ , as well as the significant correlation between the negative valence and the arousal ranks,  $r = .986$ ,  $p < .0001$ , and

the significant correlation between valence and arousal in the positive and negative gradients,  $r = .985$ ,  $p < .0001$ . The comparison of correlations from dependent samples suggested a significant difference between the appetitive and the defensive gradients,  $p = .01$ .

*Skin Conductance.* Figure 2.3B shows the relationship between skin conductance changes and arousal ratings. A significant correlation between the positive valence and the arousal ranks was detected,  $r = .91$ ,  $p < .0001$ . The correlation between the negative gradient and the arousal ranks was not significant,  $r = .60$ ,  $p = .066$ . Even though the correlation between the appetitive and the aversive slopes was not significant,  $r = .54$ ,  $p = .1$ , the comparison of correlations from dependent samples did not suggest a significant difference between the appetitive and the defensive gradients,  $p = .068$ .



**Figure 2.3.** The appetitive and aversive gradients defined by subjective evaluation (A) and by skin conductance changes (B).

## **EXPERIMENT 1, SUMMARY**

In Experiment 1 we used the evaluation task in order to investigate the differences between the appetitive and defensive gradients described by the subjective evaluation of positive and negative stimuli varying in emotional arousal. We also collected skin conductance changes as a measure of the arousal response induced by those stimuli. The results suggested a difference in the motivational gradients defined by the subjective response; specifically, in agreement with previous studies on the subjective evaluation process (Ito et al., 1998; Bradley & Lang, 1999), we found a steeper negative gradient, suggesting that, when emotional activation increases (arousal), negative stimuli are evaluated as being increasingly more significant than positive stimuli. In terms of subjective evaluation of the affective state, the present findings are in line with the negativity bias hypothesis. Conversely, the gradients described by the skin conductance changes provide different information compared to the subjective evaluation: in fact, the electrodermal activity did not differentiate positivity and negativity. Altogether, an interesting response pattern arose: the response to positive and negative stimuli varied as a function of arousal, but while the physiological response did not differentiate the appetitive and aversive gradients, the subjective evaluations suggested a steeper negative gradient. In other words, the physiological response, indexed here by skin conductance, supports the relevance hypothesis, while the subjective evaluations support the negativity bias hypothesis.

## **Experiment 2: Brain response to emotional stimuli.**

Does the brain differentiate positivity and negativity as a function of emotional significance? The results of Experiment 1 suggested mixed results: on the one hand, the subjective evaluation

suggested a steeper negative gradient, while, on the other hand, the skin conductance response did not differentiate positivity and negativity. Those data represent a perfect starting point from which to further investigate the differences in the motivational gradients in terms of brain response. The large sample of stimuli used in Experiment 1 (1200 stimuli from 12 categories within pleasant, neutral, and unpleasant content classifications) and the gradients created with the ratings of valence and arousal were used in Experiment 2 to test whether the appetitive and defensive gradients described by the neural indexes of the emotional response (LPP and Alpha-ERD) showed functional differences. The goal of this experiment is to extend the results that suggest that the LPP varies as a function of arousal (Cuthbert et al., 2000; De Cesare & Codispoti, 2006, 2008; Schupp et al., 2004), by examining whether this modulation describes functional differences in the motivational gradients (e.g., a steeper negative gradient).

One possibility is that the functional differences between the motivational gradients might occur in the motivational gradients described by the brain responses; if the motivational systems have evolved to react more strongly to negative stimuli (or events), a steeper slope for the aversive gradient, compared to the appetitive gradient, is expected to emerge in the brain response.

In this experiment, we also assessed the temporal stability of the motivational gradients as an additional method for determining the mechanisms underlying the emotional response. In Experiment 2, seven days after the initial study, participants returned to the laboratory and viewed a different set of emotional pictures. If the response to negative stimuli has a greater adaptive value compared to the response to positive stimuli, we would expect a higher correlation between the session in the brain response to negative compared to positive stimuli.

The specific aims of this study were to:

- Test the hypothesis that there is a difference between the appetitive and aversive gradients as a function of arousal, as suggested by animal learning and social literature (e.g., positivity offset and negativity bias).
- Investigate brain response (ERPs and EEG oscillations) as a function of the arousal gradient of positive and negative stimuli. Because of the adaptive value of negative information, we tested the hypothesis that a steeper aversive gradient, compared to the appetitive gradient, would reflect a difference in the evaluative process that allows us to ascribe a greater significance to aversive, compared to positive, stimuli as a function of the increasing motivational engagement (arousal).
- Investigate the temporal stability of LPP and Alpha-ERD as a function of the arousal gradient. Due to the evolutionary significance of negative information, higher temporal stability may be expected in the brain response to negative stimuli compared to positive stimuli. Otherwise, if temporal stability is related to motivational relevance, higher stability in reaction to high-arousing emotional stimuli (both positive and negative), compared to low-arousing stimuli, may be expected. Temporal stability was investigated at an inter- and intra-individual level.

## **METHOD**

### **Participants**

Twenty-four participants (12 females) took part in this study ( $M=22.85$ ,  $SD= 3.3$ ). Subjects were free from psychiatric or neurological disease or related past history, as indicated by self-report.

### **Stimuli and Equipment**

We used the same pictures as those in Experiment 1, but in Experiment 2 the entire set of stimuli (1200) was presented to each participant. Specifically, each person participated in two sessions separated by 7 days. The whole set of stimuli were divided into four subsets (300 pictures each), containing 25 pictures from each category. The presentation sequences of every subset were built with the constraints that no more than three consecutive images with the same valence could be presented, and no consecutive images with the same content would be displayed.

In each of the two sessions two of the four subsets were presented, and the presentation order was balanced across participants. At the end of the second session, each participant had seen the whole set of 1200 stimuli once.

### **Procedure**

The only difference in procedure compared to Experiment 1, was the evaluation section. In Experiment 2 participants were engaged in a free-viewing task, without carrying out any evaluation. The experimental procedure was the same for the two sessions. Subjects were seated in a dimly lit sound-attenuated room and, following informed consent, sensors were attached and the participants were instructed to simply view a series of pictures that would be presented on the screen. Each trial started with the presentation of a fixation cross (random duration from 0.5 s to 1 s) followed by the presentation of pictures (4 s) and an intertrial interval (ITI) of 2.5 s. Pictures were presented using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) on a 19" monitor.

### **EEG recording and processing**

EEG recording and Processing. The electroencephalogram (EEG) was recorded using the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands). EEG was recorded with a 73-sensor array,

with a 512 Hz sampling rate. The ERP data were referenced to the average of all scalp electrodes and low-pass filtered with cutoffs of 40 Hz, while the EEG oscillation data were not low-pass filtered. Additionally, a sensor was attached below the left eye. For each trial, EEG was corrected for blinks and eye movements using a regression technique based on the electrodes above and below the left eye, and to the left and right of the eyes. Off-line analysis was performed using EMEGS (Peyk, De Cesarei, & Junghöfer, 2011), and included artifact detection and sensor interpolation (Junghöfer, Elbert, Tucker, & Rockstroh, 2000).

**Wavelet Analysis.** A time-frequency analysis was conducted on single trial data, using complex Morlet wavelets varying in time and frequency with a Gaussian shape. The time-frequency analysis was performed using the FieldTrip software (<http://fieldtrip.fcdonders.nl/>) through EMEGS (Peyk, De Cesarei, & Junghöfer, 2011). The  $f/SD(f)$  ratio was set to 3 and the number of wavelet cycles was set to 5 (Tallon-Baudry, Bertrand, Delpuech, & Pernier, 1997). The range of analysis was from 9 to 13 Hz, and analysis was performed in time windows from .4 s before picture onset to 1.4 s after picture onset, in steps of 10 ms. The power spectrum was converted into dB (Delorme & Makeig, 2004), and the 1.5 to .5 ms baseline period preceding picture onset was subtracted from the resulting power spectrum.

### **Data Analysis**

LPP was scored as the average ERP amplitude at centroparietal sensor sites (Figure 1 in the Note Section). LPP was scored in the 250–1200 ms time interval. A baseline correction based on the 100 ms prior to stimulus onset was performed. Alpha desynchronization was scored at bilateral parieto-occipital sensor sites (Figure 2 in the Note Section) in the 400–1400 ms time interval.

The same procedure used to test the differences in the motivational gradients described by subjective evaluations was used in the present experiment. The differences in the gradients described by the LPP and the Alpha-ERD were analyzed according to the comparison of correlation from two dependent samples (Steiger, 1980).

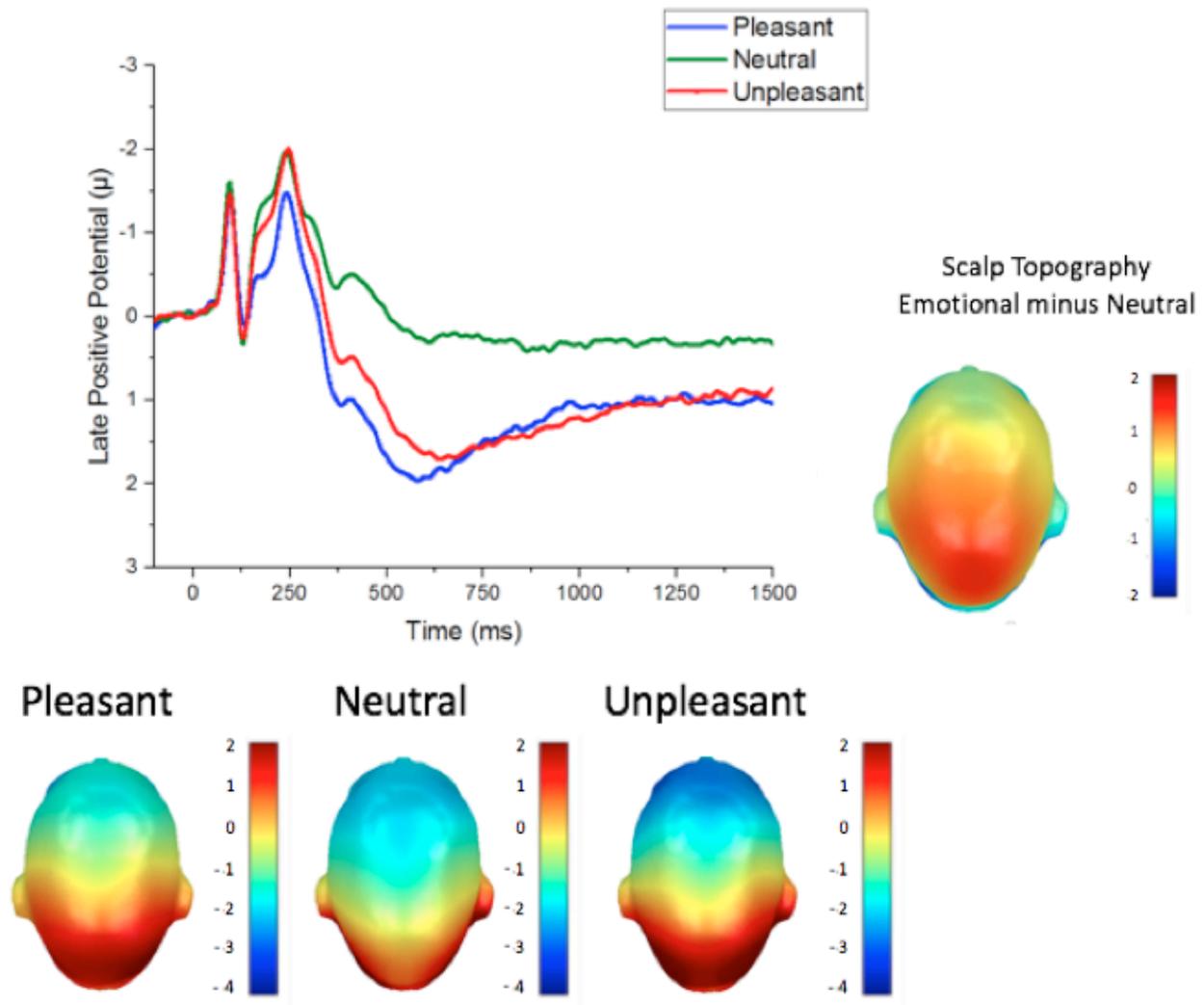
## **RESULTS**

The first section of the results, defined “Valence Section”, describes the effects of the emotional valence (positive, neutral, and unpleasant) on ERPs and Alpha-ERD responses. The results in this section are performed on the data of the 24 participants.

The second part of the results, the “Motivational Gradients Section”, focuses on the comparison between the appetitive and defensive gradients, the main goal of Experiment 2. The results of this section are concentrated, as are the results of Experiment 1, on the analysis of the stimuli.

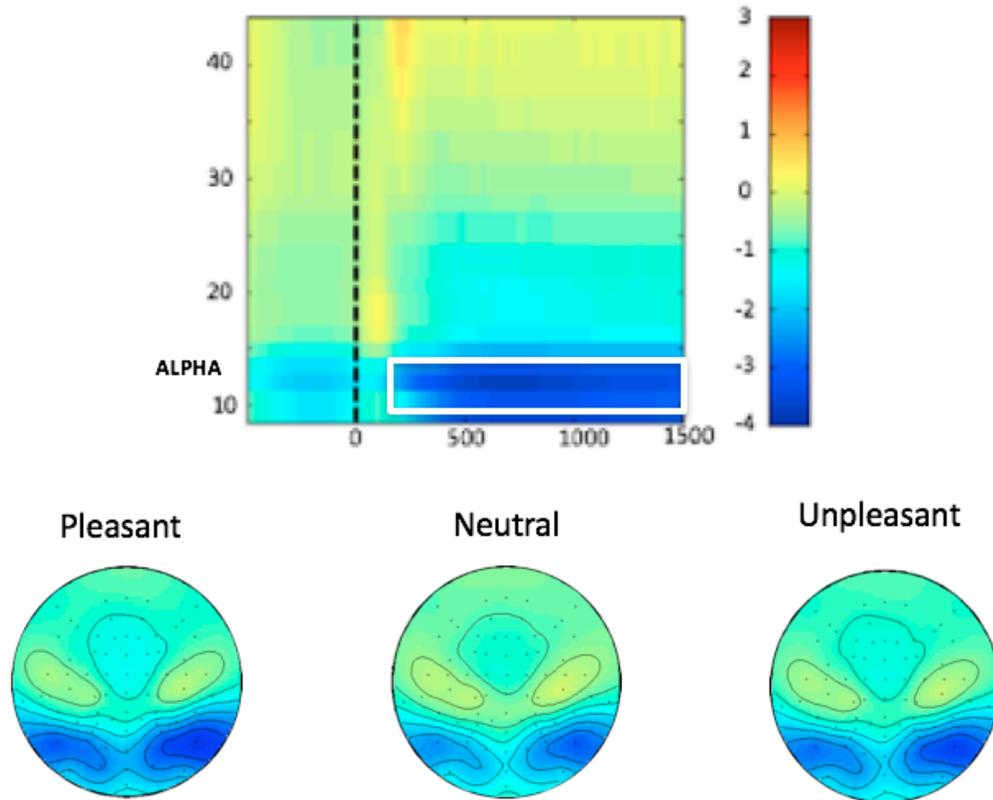
### **Valence Section**

A significant main effect of Valence was observed in the LPP window (250-1200ms),  $F(1,23)= 101,64$ ,  $p < .0001$ ,  $\eta^2_p = .815$ . This effect was further characterized by a significant quadric trend,  $F(1,23)= 190.97$ ,  $p < .0001$ ,  $\eta^2_p = 0.893$ , indicating a more positive LPP for arousing compared to neutral pictures (Figure 2.4). Pairwise comparisons are reported in Table 1 of the Note Section.



**Figure 2.4.** *Top.* Grand-average ERP waveform averaged across centro-parietal sensors used for the LPP analysis for pleasant, neutral, and unpleasant valence; on the *Right*, the ERP scalp topography (250-1200 ms) of the difference between emotional and neutral picture processing. *Bottom.* ERP scalp topography (250-1200 ms) for pleasant, neutral, and unpleasant contents.

Alpha-ERD are reported in Figure 2.5. A significant effect of Valence was observed on  $\alpha$ -ERD,  $F(1,23)=41.55$ ,  $p < .0001$ ,  $\eta^2_p = .64$ . Alpha-ERD was more pronounced in reaction to more arousing stimuli compared to less arousing and neutral stimuli, an effect described by the quadratic trend,  $F(1,23)=52.94$ ,  $p < .0001$ ,  $\eta^2_p = .697$ . The affective modulation is showed in Figure 2.5. Pairwise comparisons are reported in Table 1 of the Note Section.



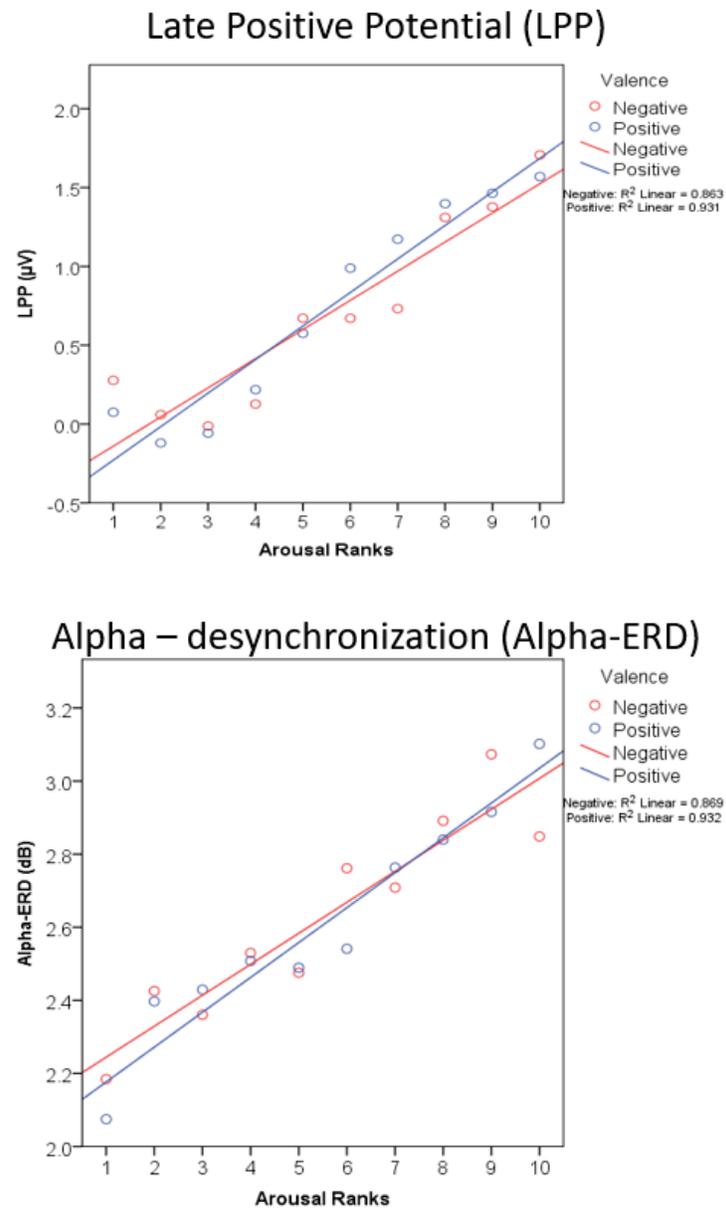
**Figure 2.5.** *Top.* Time-frequency plot for the parieto-occipital sensors used for the Alpha-ERD analysis averaged across emotional (pleasant and unpleasant) contents. *Bottom.* Scalp topography (400-1400 ms) of the Alpha desynchronization (power range -0.8, 0.4 dB) for pleasant, neutral, and unpleasant valence.

## Motivational Gradients Section

### Late Positive Potential

The motivational gradients described by the LPP are shown in Figure 2.6 (top). A significant correlation between the LPP response to the stimuli in the negative valence and the arousal ranks was detected,  $r = .9$ ,  $p < .0001$ , as well as a significant correlation between the LPP response to the stimuli in the defensive gradient and the arousal ranks,  $r = .918$ ,  $p < .0001$ . There was also a significant correlation between LPP and arousal in the appetitive and defensive gradients,  $r = .782$ ,  $p < .0001$ . The

comparison of correlations from dependent samples did not suggest a significant difference between the appetitive and aversive motivational gradients,  $p = .80$ .



**Figure 2.6.** The appetitive (in blue) and defensive (in red) gradients defined by the LPP (top) and by the Alpha-ERD (bottom). In both measures, the gradients were not different.

## Alpha-ERD

The motivational gradients described by the Alpha-ERD are shown in Figure 2.6 (bottom). A significant correlation between the negative valence and the arousal ranks was detected,  $r = -.882$ ,  $p < .0001$ , as well as a significant correlation between the negative valence and the arousal ranks,  $r = -.931$ ,  $p < .0001$ . There was also a significant correlation between valence and arousal in the positive and negative gradients,  $r = .735$ ,  $p < .0001$ . Similarly to the LPP, the comparison of correlations from dependent samples did not suggest a significant difference between the appetitive and aversive motivational gradients described by the Alpha-ERD,  $p = .487$

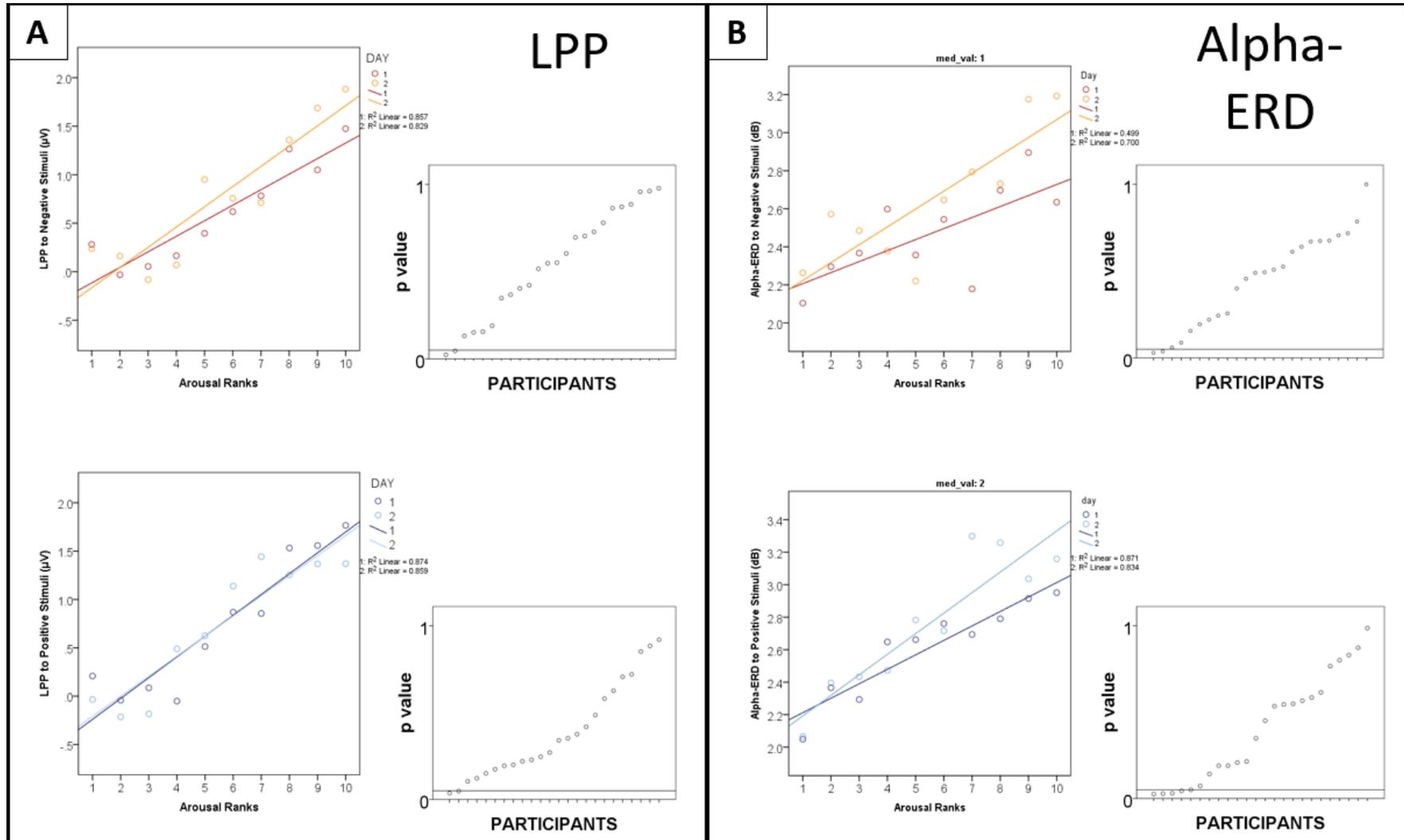
### **Temporal Stability**

To determine the temporal stability of the gradients described by the LPP and the Alpha-ERD, we used the same approach described to investigate the differences between the appetitive and aversive gradients. This time, rather than comparing the appetitive and aversive gradients directly, we compared the differences between the gradients on day 1 and day 2. Thus, a series of correlations between the arousal and aversive (or appetitive) gradients were conducted on the two different days in order to compare the correlations from dependent samples.

Figure 2.6 shows the high temporal stability of the late positive potential (Panel A) and the high temporal stability of the alpha-desynchronization (Alpha-ERD); in each session, arousing pictures prompted a larger late positive potential and alpha-desynchronization than low-arousing pictures. No differences were detected between the temporal stability of the appetitive and aversive gradients. The correlations are reported in Table 2.1.

In addition, the intra-individual temporal stability of the motivational gradients, described by LPP and the Alpha-ERD, were analyzed according to the comparison of correlations from dependent samples (Steiger, 1980). The data regarding the intraindividual temporal stability are shown in the insets of

Figure 2.7. 92 % of participants did not show a significant difference between the defensive gradients defined by the LPP or between the appetitive gradients in the two experimental sessions (for both the defensive and the appetitive gradient, 22 out of 24 participants did not show differences in the gradients between the two sessions.). Most participants also showed a similar pattern in terms of temporal stability in the Alpha desynchronization: 92% of participants did not show differences in the defensive gradient between the two sessions (22 out of 24), and 80% of them did not show differences in the appetitive gradient (19 out of 2



**Figure 2.7.** The correlation between the amplitude of the Late Positive Potential (Panel A) and the Alpha-ERD (Panel B) across Sessions 1 and 2 (separated by 7 days) for the defensive (top panels) and appetitive (bottom panels) gradients. The insets show the distribution of p values of the within-subject correlations of LPP and Alpha-ERD between the two sessions; the line indicates the cut-off value of  $p = .05$ .

Valence	Comparison	Difference Day1-Day2	Valence	Comparison	Difference Day1-Day2
<b>Aversive</b>	Arousal Ranks vs LPP Day 1 $r = .901, p < .0001$	$p = .097$	<b>Aversive</b>	Arousal Ranks vs Alpha Day 1 $r = -.706, p = .022$	$p = .45$
	Arousal Ranks vs LPP Day 2 $r = .943, p < .0001$			Arousal Ranks vs Alpha Day 2 $r = -.837, p = .003$	
	LPP Day 1 vs LPP Day 2 $r = .979, p < .0001$			Alpha Day 1 vs Alpha Day 2 $r = .626, p = .053$	
<b>Appetitive</b>	Arousal Ranks vs LPP Day 1 $r = .845, p = .002$	$p = .58$	<b>Appetitive</b>	Arousal Ranks vs Alpha Day 1 $r = -.933, p < .0001$	$p = .74$
	Arousal Ranks vs LPP Day 2 $r = .889, p = .001$			Arousal Ranks vs Alpha Day 2 $r = -.913, p < .0001$	
	LPP Day 1 vs LPP Day 2 $r = .888, p = .001$			Alpha Day 1 vs Alpha Day 2 $r = .846, p = .002$	

**Table 2.1.** The correlation between the LPP and the Alpha-ERD across the two sessions that were held a week apart. Both measures showed a high correlation in both the defensive and the appetitive gradients, without differences between the two sessions.

## EXPERIMENT 2, SUMMARY

The results of Experiment 2 clearly demonstrate that the appetitive and the defensive gradients, defined by LPP and by the Alpha-ERD, did not differentiate positivity and negativity. Moreover, both gradients showed a high temporal stability, suggesting that the supposed higher adaptive value of negative information does not lead to a higher temporal stability of the brain response to negative stimuli. Overall our data support the idea that the evaluation of emotional stimuli depends on the affective significance of the stimuli; in fact, in accordance with previous studies (Cuthbert et al., 2000; De Cesarei & Codispoti, 2011; Schupp et al., 2004), we found that the brain response varies as a function of the arousal of the stimuli. In addition, we found that the brain response, here indexed by the Late Positive Potential and by the alpha- desynchronization, does not functionally differentiate appetitive and defensive responses.

## Intermediate Summary: The Motivational Gradients

The bottom line of our results is that evaluation clearly depends on the emotional significance of the stimuli. When the motivational engagement increases, that is, when emotional stimuli are increasingly rated as more pleasant, they are increasingly rated as being more significant and prompt a larger brain response (in terms of LPP and alpha-desynchronization). However, the different indexes used to investigate evaluation provide mixed information about the functional differences between positivity and negativity.

The results of Experiment 1 support the assumption that the subjective evaluation of emotional stimuli differentiates positivity and negativity, with a steeper negative gradient. According to the negativity bias hypothesis, these results suggest that the defensive system provides a stronger response to negative stimuli compared to the appetitive system, probably because of the greater adaptive value of the negative information (Cacioppo et al., 1997). However, the physiological response seems to suggest a different pattern: in Experiment 1, the motivational gradients described by skin conductance changes showed a considerable overlap between the motivational systems, without differentiating them. A similar conclusion is supported by the data of Experiment 2, with LPP and Alpha-ERD showing a similar modulation in response to emotional stimuli that vary in emotional significance, without a differentiation between positivity and negativity.

## CONCLUSIONS

Therefore, does the evaluative process functionally differentiate positivity and negativity? On one hand, even though the subjective evaluation of emotional stimuli has been interpreted as reflecting differential motivational organizations that allow us to react more strongly to threatening stimuli (Cacioppo et al, 1997), they are executed after a sequence of processing stages that are influenced by cultural expression rules and by subjective control. On the other hand, the LPP and the Alpha-ERD are a much more temporally proximal measure of the evaluative processes involved (De Cesarei & Codispoti, 2011). At this stage of the information processing, the stimulus significance drives the evaluative process and does not reflect functional differences between positive and negative valence. The high temporal stability of the motivational gradients further supports this hypothesis, as no advantage of the aversive gradient in terms of temporal stability was detected.

## **The next steps: affective attentional bias toward negative stimuli?**

At this point, we can conclude that the evaluative process is differently modulated by the affective information as a function of the emotional processing stages considered. To take this conclusion one step further, in the following section we will examine how affective connotations of the visual scene impact on the attentional engagement. Specifically, we will test the hypothesis that the negativity bias, here defined as a greater attentional engagement toward negative compared to positive stimuli, might arise when positive and negative stimuli compete for attentional resources. The main question of the following section is: Can negative information capture more attentional resources than positive information can?

# Chapter 3

## Attentive capture of multiple high-arousing stimuli

As previously described, rapid evaluations of whether a stimulus is helpful or dangerous are crucial to the correct and timely execution of motivated behavior: for example, approaching a potential reward or fleeing from a potential threat. Because survival depends on the ability to evaluate the emotional significance of the stimuli, as we monitor the environment in everyday life, we evaluate relevant stimuli even when not explicitly intending to do so.

In fact, emotional cues activate cortico-limbic appetitive and defensive systems which engage attentional resources that interfere with performance (by elongating reaction times) in concurrent tasks (Bradley, Cuthbert, & Lang, 1999; Bradley, Drobles, & Lang, 1996; Codispoti et al., 2016; De Cesarei & Codispoti, 2008; Schimmack, 2005; Verbruggen & De Houwer, 2007).

Even though some studies have suggested that unpleasant stimuli capture greater attention than pleasant stimuli do (Hartikainen, Ogawa, & Knight, 2000; Ohman, Lundqvist, & Esteves, 2001; Pratto & John, 1991), an increasing body of evidence suggests that, when pleasant and unpleasant stimuli are equated in terms of arousal ratings, no difference as a function of valence is found, and highly arousing picture contents (pleasant and unpleasant) capture greater attentional resources than low arousing stimuli (Blair et al., 2007; Bradley et al., 1999; Bradley, Drobles, & Lang, 1996; Nummenmaa, Hyona, & Calvo, 2006; Schimmack, 2005; Verbruggen & De Houwer, 2007).

However, as originally described by Cacioppo and colleagues, the adaptive value of the negativity bias emerges when a negative threatening stimulus appears near a positive stimulus, or in a pleasant

context. In fact, when a stimulus elicits a low level of activation, the exploratory behavior that is generated may place the organism in the proximity of hostile stimuli. Because it is more difficult to reverse the consequences of a harmful activity than one that is simply left unexplored, natural selection may have resulted in discernable motivational organizations with the propensity to react more strongly to negative than positive stimuli, resulting in the negativity bias (Cacioppo et al., 1997). From this perspective, it is possible to hypothesize that the negativity bias, that is, a greater attentive capture to negative stimuli, might occur when a negative stimulus appears either in proximity to a positive one, or in a pleasant context. In order to address this issue, we conducted two experiments. In Experiment 3 we presented a pair of emotional distractors simultaneously, while participants were engaged in a visual search task. The distractor pairs could be two neutral pictures, one neutral and one emotional (pleasant or unpleasant) pictures, two emotional pictures of the same valence (pleasant or unpleasant), or, crucially, two high-arousing emotional pictures of the opposite valence (one pleasant and one unpleasant). In Experiment 4, we used a priming task: prime and target could be pleasant, neutral, or unpleasant, and participants were engaged in a visual search task for the target stimulus. In both studies, we tested whether the distractor pairs made up of a pleasant and an unpleasant stimulus showed a greater attentive capture (greater RT slowdown) compared to the other conditions, suggesting a greater attentional engagement when negative stimuli were presented near positive ones, or were primed by positive stimuli.

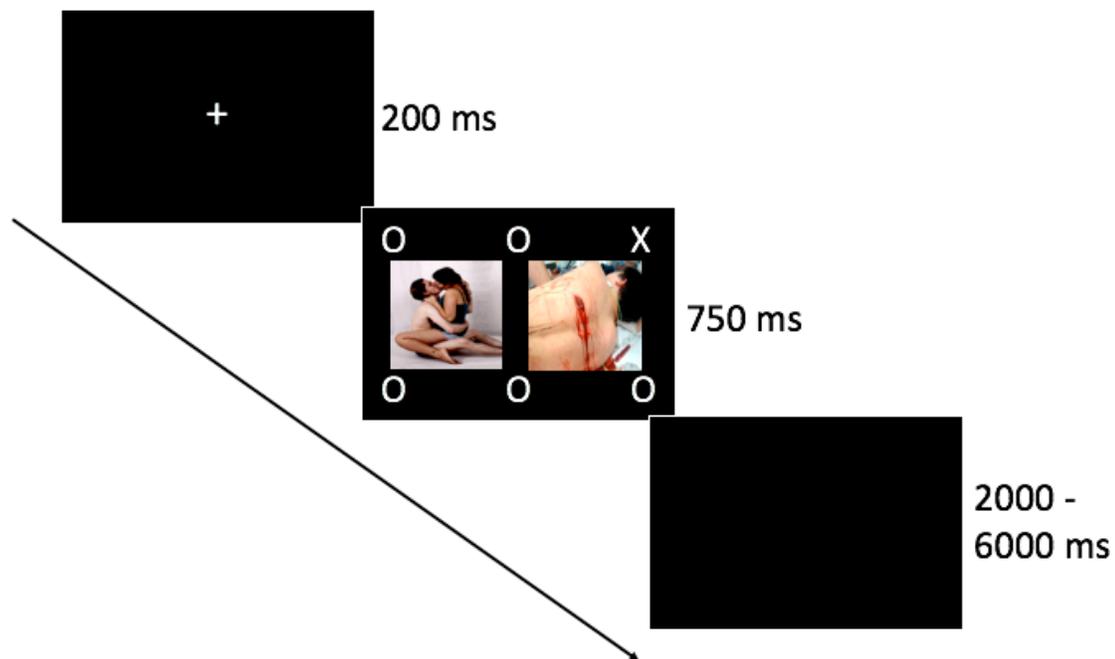
### **Experiment 3: Simultaneous presentation of distractor pairs**

#### **METHOD**

##### **Participants**

Fifty-seven participants took part in the experiment and provided written informed consent, as approved by the Institutional Review Board of the University of Maryland, College Park.

Participants were free from psychiatric or neurological disease or related past history, as indicated by self-report. Data from one participant were excluded because of poor performance (accuracy below 50%). Thus, the results reported here are based on data collected from 56 participants (32 female;  $19.4 \pm 1.5$  (SD) years old).



**Figure 3.1.** Experimental design. Each trial started with a fixation cross and was followed by a stimulus display composed of two distractors with two letter strings in a horizontal row above and below the pictures. The participant's task was to indicate whether an 'X' or an 'N' appeared among a series of 'O's.

### Stimuli and Task

Each trial in the main run started with the presentation (200ms) of a fixation cross. Next, a stimulus display consisting of two color images with two letter strings of three letters each appeared for 750ms in a horizontal row above and below the images (Figure 3.1). One target letter (X or N) and five non-

target letters ('O') were presented in a random order in each trial. Participants were required to search the letter string for a target letter (either X or N) and respond rapidly using the numerical keypad. Participants were instructed to ignore the distractor images. The stimulus display was followed by a variable intertrial interval of 2 to 6 seconds. Three classes of images were employed: positive, neutral, and negative. Positive images consisted of erotic photographs, neutral pictures consisted of people in neutral daily activities (such as walking in the street) and negative images consisted of photographs of mutilated bodies. Four hundred eighty pictures (144 pleasant, 192 neutral and 144 unpleasant) were selected from various sources including the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and Internet. These pictures were arranged into six different pairs of distractors: Neutral-Neutral, Neutral-Pleasant, Neutral-Unpleasant, Pleasant-Pleasant, Unpleasant-Unpleasant, Pleasant-Unpleasant. For the presentation of visual stimuli and the recording of participants' responses, Presentation software (Neurobehavioral Systems, Albany, CA) was used.

Before starting the main runs, a practice run was performed with neutral pictures used as distractors. After the practice, participants performed a total of four experimental runs, totaling 48 trials per condition (288 trials in the whole experiment). Eight different trial sequences with a randomized picture content was used.

### **Data Analysis**

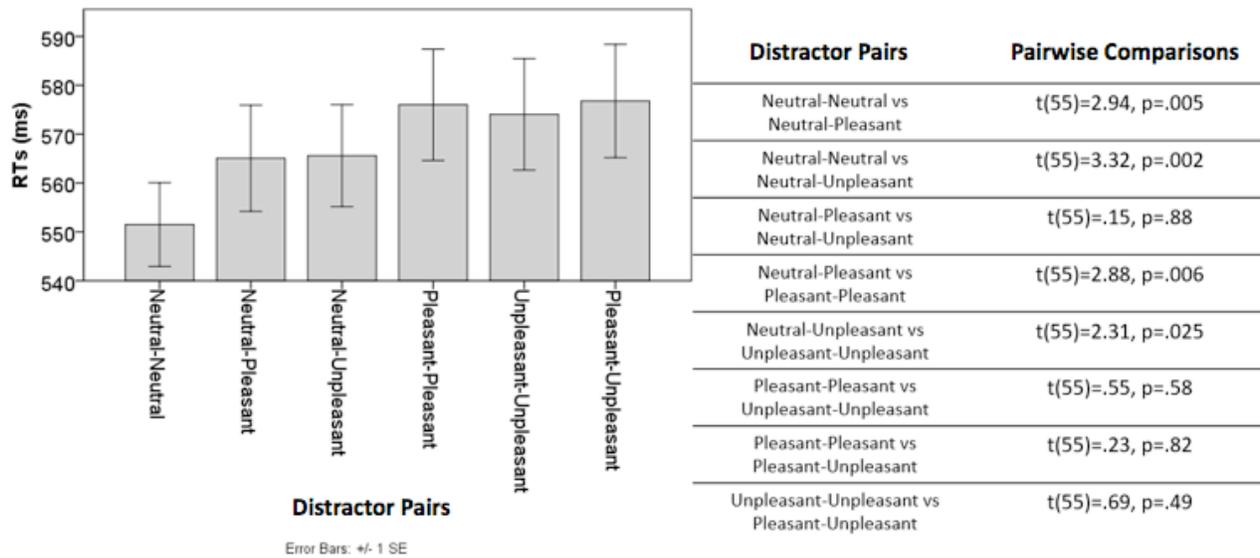
In the past, the interference induced by emotional distractors in terms of RT data has been investigated (Erthal et al., 2005; Padmala & Pessoa, 2014). Therefore, we mainly focused on RT data but additional analyses of accuracy data were also conducted. For the RT analysis, error trials and

trials with an RT exceeding 3 SD from the condition's specific mean were excluded for each participant, resulting in 5.84% of the trials being excluded. For each participant, mean RT and accuracy rate data were determined as a function of Distractor Pairs (6 levels), and repeated-measures analyses of variance (ANOVAs) were conducted. We used an alpha level of 0.05 for all statistical tests.

## RESULTS

A repeated-measure ANOVA on the RTs factoring the emotional distractor pairs [The Geisser-Greenhouse correction (Greenhouse & Geisser, 1959) was used] turned out to be significant,  $F(5,275) = 10.73$ ,  $p < .0001$ ,  $\eta^2_p = 0.163$ . In order to investigate the differences between the 6 distractor pairs, a series of t-tests were performed (See Figure 3.2). The pairwise comparisons showed that (1) the pairs with two neutral distractors elicited less interference compared to the other conditions, (2) the interference effect induced by two arousing stimuli was greater than the interference induced by one arousing and one neutral picture, and (3) no differences in behavioral interference were found when comparing distractor pairs made up of two high-arousing stimuli of the same valence (pleasant or unpleasant) with pairs made up of a pleasant and an unpleasant distractor (Figure 3.2).

We also evaluated accuracy data (see Figure 2) according to a one-way ANOVA with 6 levels,  $F(5,275) = 1.42$ ,  $p = .23$ .



**Figure 3.2.** Behavioral interference varies as a function of the number of arousing stimuli presented in the visual scene. The slowdown in response was greater when two arousing distractors were presented during the visual search task, regardless of distractor valence (Pleasant-Pleasant, Unpleasant-Unpleasant, Pleasant-Unpleasant). The table shows the pairwise comparisons between the distractor pairs. Error bars denote the standard within-subject error term.

### EXPERIMENT 3, SUMMARY

Overall, the results of Experiment 1 demonstrate that attentive capture, and the consequent behavioral interference, depends on the number of arousing stimuli, regardless of the valence of the pictures which constitute the visual scene. The modulation of capture is consistent with previous reports (De Cesarei & Codispoti, 2008; Codispoti et al., 2016), with greater attentive capture for emotional compared to neutral pictures. However, a novelty lies in the fact that this pattern was observed when comparing neutral pairs with (1) pairs comprising one emotional and one neutral stimulus and (2) pairs made up of two emotional distractors. Although several studies have suggested that we are able to process multiple stimuli presented simultaneously without any additional cost in terms of processing time (Rousselet et al., 2002; 2005), we directly investigated the attentive costs of multiple emotional distractors by using natural scenes. Moreover, we observed that the interference

effect of single positive and negative distractor stimuli was the same as that of the two positive or two negative distractor stimuli.

Why does attentive capture not provide information about the valence interaction? Since our perceptual system serves the adaptive function of rapidly identifying whether a stimulus is helpful or dangerous, it is possible to speculate that the evaluative system has to process all incoming stimuli in the same way, regardless of valence. This is particularly true when multiple stimuli are presented simultaneously.

#### **Experiment 4: Alternation of distractor pairs**

Experiment 3 provided evidence that the attentive capture of high-arousing emotional stimuli is primarily driven by the emotional significance of the stimuli, regardless of their valence, even when positive and negative arousing stimuli simultaneously compete for attentional resources. However, as described in the introduction of this chapter, it is possible that the negativity bias takes place when a negative stimulus appears in a positive context. Hence, the question remains open regarding whether a greater attentional engagement to negative stimuli is present when a negative stimulus is presented in a pleasant context or is preceded by a pleasant stimulus. Based on the results of Experiment 3, we introduced a priming-like task in order to better understand the role of emotional valence in attentive capture when emotional distractor pairs are presented in rapid alternation, one at a time.

In the classical sequential semantic priming paradigm, the participants view a sequence of stimulus pairs in which the semantic or associative relationship between the first (prime) and second (target) stimulus is manipulated. Participants respond to the target stimulus (e.g., *dog*), and their responses are typically faster when the target is semantically or associatively congruent with the prime (e.g., *cat*)

compared to incongruent (e.g., *chair*). Fazio et al. (1986) altered the sequential semantic priming paradigm by varying evaluative congruity between the prime and target instead of semantic and associative congruity. This revealed that subjects pronounced target adjectives (e.g., *repulsive*) to be good or bad more quickly when they were preceded by evaluatively congruent (e.g., *spider*) primes, compared to those that were incongruent (e.g., *party*). This study was significant because it suggested that attitudes could quickly be brought to mind with little deliberation, potentially biasing the way people view their environment and behave within it. This task has been extensively used in the past twenty-five years, also within studies on patients with different disorders (Asgaard, Gilbert, Malpass, Sugai, & Dillon, 2010; Dannlowski et al., 2006; Degner & Wentura, 2010; Dovidio, Evans, & Tyler, 1986; Eves, Scott, Hoppé, & French, 2007; Fazio, Jackson, Dunton, & Williams, 1995; Goubert, Crombez, Hermans, & Vanderstraeten, 2003; Kerns, 2005; Milanak & Berenbaum, 2009; Perdue, Dovidio, Gurtman, & Tyler, 1990; Perdue & Gurtman, 1990; Roefs et al., 2005; Scherer & Lambert, 2012; Suslow, Arolt, & Junghanns, 1998; Suslow, Dannlowski, Arolt, & Ohrmann, 2010; Suslow, Roestel, Droste, & Arolt, 2003; Vandenbosch & De Houwer, 2011; Veldhuizen, Oosterhoff, & Kroeze, 2010; Vermeulen, Luminet, & Corneille, 2006; Weisbuch & Ambady, 2008), and several reviews have been written describing the mechanisms underlying emotional priming (see De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009; Fazio, 2001; Fazio & Olson, 2003; Ferguson & Bargh, 2003; Klauer, 1998; Klauer & Musch, 2003; Spruyt, Gast, & Moors, 2011; Wentura & Degner, 2010; Wentura & Rothermund, 2003; Wittenbrink, 2007).

There is extensive debate in the literature concerning the affective priming effect: specifically, the idea that the encoding advantage observed regarding the target preceded by a prime of the same valence has recently been attributed to the evaluative task (e.g., Herring et al., 2013; Werner &

Rothermund, 2013). The purpose of Experiment 4, however, is not to investigate the modulation of the priming effect. As introduced in this section the goal of the present experiment is to investigate the possibility that a greater attentional engagement to negative compared to positive stimuli might be observed when a negative stimulus is presented in a pleasant context or is preceded by a pleasant stimulus. To this purpose, the participants in our experiment were not engaged in the evaluative categorization of the stimuli; rather, they were engaged in a visual search task for the target stimuli with the explicit instruction to ignore the pictures.

## **METHOD**

### **Participants**

Fifty-eight participants took part in Experiment 2 and provided written informed consent, as approved by the Institutional Review Board of the University of Maryland, College Park. Data from one participant was excluded from the analysis because of poor performance (below 50% of accuracy). Thus, the results reported in this study are based on 57 participants (32 females;  $20.5 \pm 1.5$  (SD) years old).

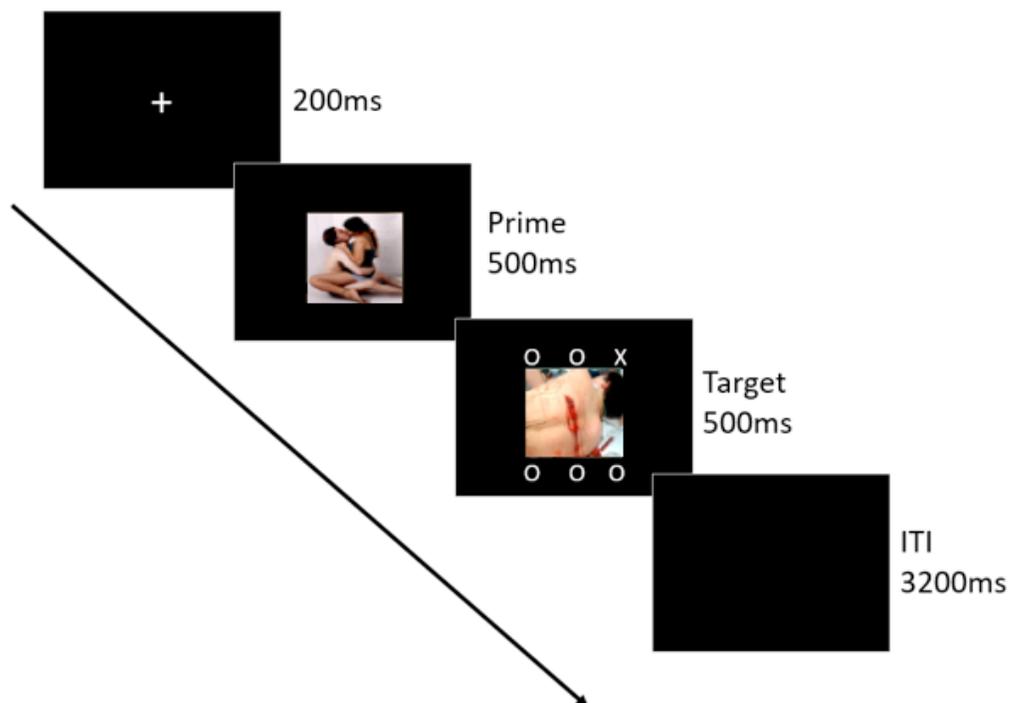
Participants were free from psychiatric or neurological disease or related past history, as indicated by self-report.

### **Stimuli and Task**

In Experiment 4 the pictures that made up the pairs of distractors were presented in a short sequence, one at a time (Figure 3.3). The first picture of each pair, from now on called the Prime, was presented alone. Next, a Target display appeared, consisting of a color image with two letter strings of

three letters each appearing in a horizontal row above and below the images. One target letter (X or N) and five non-target letters ('O') were presented in a random order in each trial. Participants were required to search the letter string for a target letter (either X or N) and respond as quickly as possible using the numerical keypad. Participants were instructed to ignore the distractor images (both Prime and Target).

The same pictures as those of Experiment 1 were used (144 pleasant, 192 neutral and 144 unpleasant). According to a statistical design with factors Prime valence (positive, neutral, negative) and Target valence (positive, neutral, negative), 9 pairs of distractors were created. After a practice run (in which only neutral distractors were presented), participants performed a total of 4 experimental runs, totaling 48 trials per condition (482 in the whole experiment). The pictures used in the first two runs were repeated in the last two in different Prime-Target pairs.



**Figure 3.3.** Experimental design. Each trial started with a fixation cross and was followed by a Prime display showing one picture (500ms) and then by a Target display (500ms) composed of one distractor with two letter strings in a horizontal row above and below the picture. The participant's task was to indicate whether an 'X' or an 'N' appeared among a series of 'Os'.

### Data Analysis

As in the previous experiment, we mainly focused on RT data but additional analyses of accuracy data were also conducted. For the RT analysis, error trials and trials with an RT exceeding 3 SD from the condition specific mean were excluded for each participant, resulting in 6.61% of the trials being excluded. Mean RT and accuracy rate data were determined as a function of Prime valence (3 levels) and Target valence (3 levels), and repeated-measures analyses of variance (ANOVAs) were conducted. We used an alpha level of 0.05 for all statistical tests.

## RESULTS

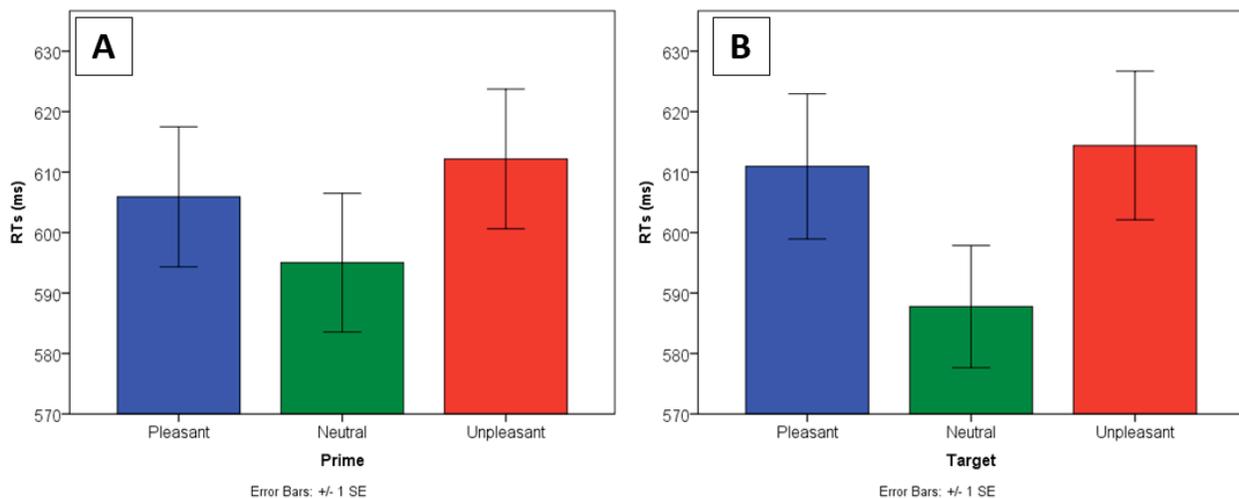
RT data (Figure 3.4) were evaluated according to a 3 x 3 (Prime Valence [positive, neutral, negative] x Target Valence [positive, neutral, negative]) repeated-measures ANOVA.

Analysis of RTs yielded a significant effect of Prime Valence,  $F(2, 114) = 20.64$ ,  $p < .0001$ ,  $\eta^2_p = 0.266$ , indicating slower RTs for emotional (pleasant and unpleasant) compared to neutral scenes,  $F(1, 57) = 29.22$ ,  $p < .0001$ ,  $\eta^2_p = .337$ , and a significant difference between pleasant and unpleasant stimuli,  $F(1, 57) = 7.77$ ,  $p = .007$ ,  $\eta^2_p = .12$ , suggesting slower RTs after unpleasant (616 ms) compared to pleasant primes (609 ms).

A significant main effect of Target Valence emerged,  $F(2, 114) = 15.86$ ,  $p < .0001$ ,  $\eta^2_p = 0.218$ , indicating slower responses for emotional (pleasant and unpleasant) compared to neutral scenes,  $F(1, 57) =$

63.81,  $p < .0001$ ,  $\eta^2_p = .528$ , and no differences between pleasant and unpleasant stimuli,  $F(1, 57) < 1$ ,  $p = .33$ . The interaction Prime Valence x Target Valence was not detected,  $F(4, 228) = 1.77$ ,  $p = .14$ .

We also evaluated accuracy data according to a 3 x 3 (Prime Valence [positive, neutral, negative] x Target Valence [positive, neutral, negative]) repeated-measures ANOVA. No significant main effects of Prime Valence,  $F(2, 114) < 1$ ,  $p = .95$ , and Target,  $F(2, 114) = 1.07$ ,  $p = .35$ , nor the interaction were detected,  $F(4, 228) < 1$ ,  $p = .64$ .



**Figure 3.4.** Behavioral interference is greater for the emotional primes compared to the neutral ones (A), and for the emotional compared to the neutral targets (B). Error bars denote the standard within-subject error term.

## EXPERIMENT 4, SUMMARY

Overall, Experiment 4 suggested a greater interference effect induced by emotional compared to neutral distractors. The novelty of the present experiment lay in the findings regarding the temporal dynamics of attentive capture. In fact, our data suggested that the behavioral interference recorded

for the Target is greater when an emotional picture, compared to a neutral one, is presented as prime. Interestingly, the negative prime seems to have greater behavioral interference compared to the pleasant prime. One possible concern about this result might be the differences in the arousal levels of the stimuli. However, the fact that (1) we used only high arousing appetitive and aversive contents (for an extensive discussion, see Schupp et al., 2004), (2) we used the same stimuli in Experiment 3, in which no differences in the attentive capture of appetitive and aversive stimuli were detected, and (3) the same stimuli, with different randomization, were used as primes or targets, leads us to the conclusion that this effect might be due to functional differences in the appetitive or aversive processing (see the general discussion of Experiment 3 for further details).

The other important result of Experiment 4 was the attentive capture of the target. The attentive capture of the emotional targets (both pleasant and unpleasant) was greater compared to the attentive capture on neutral targets. Importantly, no differences were found in the interference effect induced by pleasant and unpleasant scenes. However, the prime valence did not modulate the behavioral interference pattern recorded for the target. Thus, the capture seems to be driven by the significance of the scene rather than the interaction between valences. It is probable that the fact that we need to evaluate all potential threats or rewards did not allow the attentional engagement to be modulated by an interaction between the valences; at least, this is what happened with the temporal characteristics used in the present experiment (500ms for prime and 500ms for target).

**Intermediate Summary: Attentive capture of multiple high-arousing stimuli**

The results of Experiments 3 and 4 support the assumption that emotional high-arousing task-irrelevant stimuli, regardless of their valence, draw more on attentional resources, thus leaving them less available for task processing. First, when emotional stimuli simultaneously compete for attentional resources, the behavioral interference with the main task is related to the number of arousing stimuli in the visual scene. That is, the attentive capture is greater when two high-arousing stimuli compete for attentional resources compared to when there are distractor pairs with one emotional and one neutral distractor, or two neutral distractors. Interestingly, the interference effect induced by one positive and one negative distractor together did not differ from the effect induced by distractor pairs containing two stimuli with the same valence (both pleasant or both unpleasant). Thus, Experiment 3 suggests that the negativity bias did not emerge when negative stimuli were presented near positive ones, as originally proposed by Cacioppo (Cacioppo et al., 1997). Moreover, the negativity bias did not occur even when negative target stimuli were primed by positive ones in rapid alternation (Experiment 4). In fact, Experiment 4 suggests that the attentive capture is greater for high-arousing compared to positive stimuli, and the interference effect induced by the target is not modulated by the prime.

## **CONCLUSIONS**

In summary, the results of Experiments 3 and 4 support the view that emotional visual stimuli can be evaluated rapidly even without intention, as suggested by the greater interference effect induced by emotional compared to neutral stimuli, and appetitive and defensive stimuli are not differentiated in terms of attentional engagement. These results emerged even despite negative stimuli being

presented near positive stimuli or being primed by positive stimuli, ideal conditions in which to test the negativity bias hypothesis in the attentional domain. The present results indicate that the allocation of attentional resources to emotional stimuli is related to the emotional significance of those stimuli, regardless of their valence.

## The Next Steps: Affective bias in saccadic behavior

At this point, we can conclude that affective information of visual stimuli can be extracted rapidly and unintentionally, and the differentiation between appetitive and aversive contents may happen only in later stages of the information processing, as indexed by the subjective evaluation of the affective reactions. To take this conclusion one step further, in the following section we will examine how the affective connotation of a picture presented outside the foveal vision influences saccadic behavior. The main question of the following section is: can negative stimuli receive preferential processing and speed up the saccadic response? Is this pattern affected by the disengagement from an emotional stimulus? In the following section, we will investigate these questions by employing eye-tracker methodology that allows us to evaluate the saccadic response in a dynamic task.

## Chapter 4

## Evaluation of emotional stimuli in a dynamic task

With studies in animals as a starting point (Schneirla, 1959), the idea that exploratory behavior in human beings might reflect the approach-behavior pattern has been widely investigated. However, exploratory behavior is not only performed with effectors like arms and legs. In fact, we also make fast ballistic eye movements called saccades to explore the environment around us. Saccades are necessary to quickly bring the fovea, the part of the retina with the highest acuity, to different parts of the visual scene. Differently from other effectors, such as arms and legs, saccade programming and saccadic movements involve the activation of the motor system and spatial attention (Rizzolatti, Riggio, Descola, Umiltà, 1987). In fact, as suggested in the Premotor Theory of Attention (Rizzolatti et al., 1987), the oculo-motor system may have an important role in selective spatial attention (Rizzolatti, Riggio, & Sheliga, 1994). The hypothesis that saccadic behavior might be related to the approach-avoidance pattern has recently been supported by Deuter and colleagues (Deuter, Shilling, Huehl, Blumenthal, & Schachinger, 2013), who found delayed saccades toward negative stimuli and away from positive stimuli.

The approach-avoidance pattern has also been used to describe the functional differences between the appetitive and defensive systems. In fact, as suggested by Cacioppo (Cacioppo et al., 1997), human beings and animals show a weak tendency to approach in situations that involve a low level of activation. Because this approach behavior might take the organism near a potential threat, some species have evolved to react more strongly to negative stimuli at a high level of activation compared to positive stimuli, a phenomenon called the negativity bias. Thus, if we consider the adaptive function of positive and negative stimuli, it should be more important to detect unpleasant stimuli than pleasant ones, as missing a threat-related cue seems more costly in terms of survival than

missing a reward. In order to assess the extent to which pleasant and unpleasant visual stimuli presented extrafoveally capture attention and impact eye movement control, McSorely and van Reekum (2013) examined deviations in saccade metrics in the presence of emotional image distractors that were in proximity to a non-emotional target. The authors found that the saccade landing position was pulled toward unpleasant distractors, and that this pull was due to the quick saccade responses, supporting the negativity bias hypothesis.

Overall, the hypothesis that saccadic behavior might be related to a valence-specific mechanism (approach-avoidance) is only partially supported. Conversely, a systematic research program conducted by Calvo and colleagues suggests that the saccade response pattern is related to the arousal of the stimuli, with fast saccades toward emotional high-arousing stimuli (both pleasant and unpleasant) compared to neutral stimuli (Calvo & Lang, 2005; Calvo, Gutierrez-Garcia, Del Libano, 2015; Calvo, Nummenmaa, Hyönä, 2008; Nummenmaa, Hyönä, Calvo, 2009).

The studies that investigate how emotional stimuli impact saccadic behavior have used tasks in which the saccadic movement starts from a neutral position (usually a fixation cross) and goes to an emotional (pleasant or unpleasant) or a neutral stimulus. However, in a natural environment, emotional stimuli may cluster in time and space and, accordingly, people may encounter congruent streams or contexts of pleasant and unpleasant stimuli. From this perspective, moving the eyes from one stimulus to another may involve shifting the gaze not only from a neutral stimulus to an emotional one, but also between emotional stimuli. Importantly, moving the eyes from and to emotional stimuli involves two distinct aspects of spatial attention: attentional engagement and attentional disengagement. In fact, as originally described by Posner, Inhoff, Friedrich and Cohen

(1987), spatial attention can be separated into three operative components: disengaging from the current location, moving to a new location, and engaging the new location.

Our goal in Experiments 5 and 6 was to examine both the disengagement and the engagement component of spatial attention in a dynamic instructed saccade task. Specifically, emotional pictures were presented, changing places on the screen in a continuous stream, and participants were instructed to follow them with their eyes. We tested the competing hypothesis that the saccadic behavior might be related to the valence of the stimuli (approach-avoidance vs. negativity bias) or may be related to the emotional significance of the stimuli (arousal), in both the engagement and the disengagement component of spatial attention.

This main hypothesis was tested in two experiments. In Experiment 5, the emotional (pleasant or unpleasant) stimuli alternated in a random order within the visual scene, while in Experiment 6 there was a systematic association between emotional contents and spatial positions.

### **Experiment 5: Instructed saccades in a dynamic task**

In Experiment 5 we examined the extent to which emotional stimuli affected the engagement and disengagement from emotional stimuli in an instructed saccade task. More specifically, participants were asked to move their eyes toward the target picture presented in the visual scene every time it moved. The picture could appear in one of four positions. When the target picture changed position, its movement could be horizontal or vertical (there were no oblique movements), with an equal likelihood. Participants were simply told to follow the presentation; picture content was completely task-irrelevant.

## **METHOD**

### **Participants**

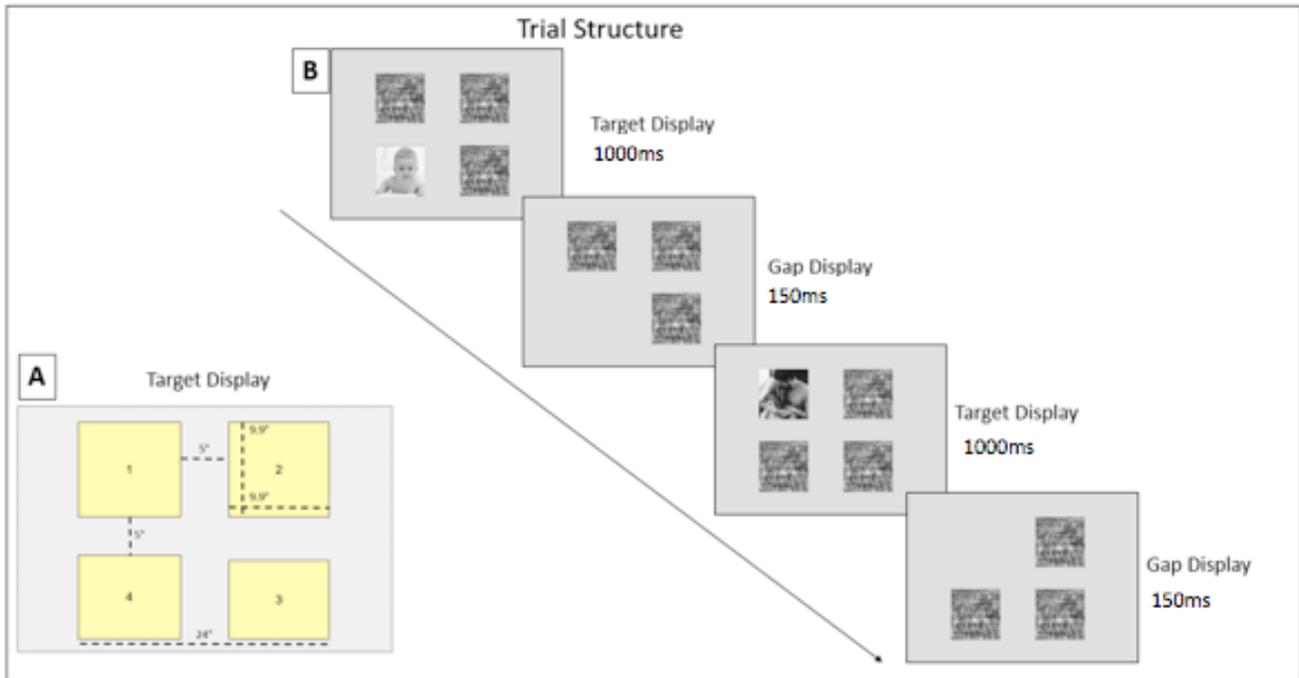
Thirty-two participants took part in Experiment 5 and provided written informed consent. Data from four participants were excluded because of poor performance (accuracy below 50%). Thus, the results reported here are based on data collected from 28 participants, ranging from 19 to 26 years old.

### **Stimuli and Task**

The experiment was carried out using the alternation of two displays, the Target Display and the Blank Display. The Target Display (Figure 4.1) contained 3 scrambled images (same scrambled image repeated 3 times) and one emotional picture (positive, neutral, or negative). The Target Display (1000 ms) was followed by a Blank Display (150 ms; Figure 4.1) composed of the 3 scrambled images (presented in the same positions as those that they had previously occupied in the Target Display) and a blank in the position that had previously been occupied by the emotional picture. The experiment was carried out by continuously alternating these two displays. The participants were instructed to follow the movements of the emotional pictures on the screen with their eyes while we recorded their movements. Crucially, from time to time, the picture might change position, moving horizontally or vertically with the same probability (50%), but no oblique movements were performed.

Based on the arousal ratings and the physiological data from previous studies (and based on our data from Study 1, reported in the previous chapter), three classes of images were used: positive, neutral, and negative. Positive images consisted of erotic photographs (84), romance (86) and babies (86); neutral pictures consisted of people in neutral daily activities: moving people (177), static people indoors (182 pictures), and static people outdoors (174 pictures); negative images consisted of

photographs of mutilated bodies (84), illness (86), and human attack (86). In total, 1047 pictures were used in the present experiment. All pictures were converted to grayscale and equated to the same frequency spectra, brightness, and contrast using a MATLAB-based toolbox (Willenbockel et al., 2010).



**Figure 4.1.** The Target Display dimension and distances (A) and an example of the sequences of events (B).

Before starting the main runs, a practice block was performed: 19 neutral pictures were used to perform 18 movements between neutral pictures. After the practice session, 4 experimental blocks were performed, 2 blocks with positive and neutral stimuli, and 2 blocks with negative and neutral stimuli. Half of the participants started with the two positive-neutral blocks, and the other half with the negative-neutral stimuli. The experimental blocks consisted of 257 pictures used to create 256 movements. In total, 1024 movements (trials) were performed. The statistical design of the experiment consisted of 8 conditions [Block Valence (2 levels: Positive, Negative) x Start Valence (2 levels: Emotional, Neutral) x End Valence (2 levels: Emotional, Neutral)]. Each one of the 8 conditions consisted of 128 trials.

### **Apparatus: Saccade recording and scoring**

Participants were seated in front of a SMI RED 500 remote eyetracking system, positioned below a 22-in LCD monitor, on which the pictures were presented, situated approximately 60 cm from the participant's head.

The eye movements were acquired continuously, at a rate of 256 samples per second. Data were analyzed using ILAB (Gitelman, 2002). Only correct saccades were entered in the saccade latency analysis, that is, only the first saccade that participants performed that started and ended in the correct position. Of the correct saccades, those faster than 80 ms from the onset of the target display and longer than 2.5 SD from the average were excluded.

### **Data Analysis**

Three variables were entered into the data analysis. The first was the valence of the experimental blocks. As previously described, participants took part in blocks containing positive and neutral stimuli and blocks made up of negative and neutral stimuli. The Block Valence variable in our analysis took into account the differences in valence of the blocks. The Start Valence and End Valence variables described the valence of the picture from which the eye movement started and the valence of the image where the gaze arrived. The interaction with the Block Valence variable was expected to be significant as part of the approach-avoidance scenario.

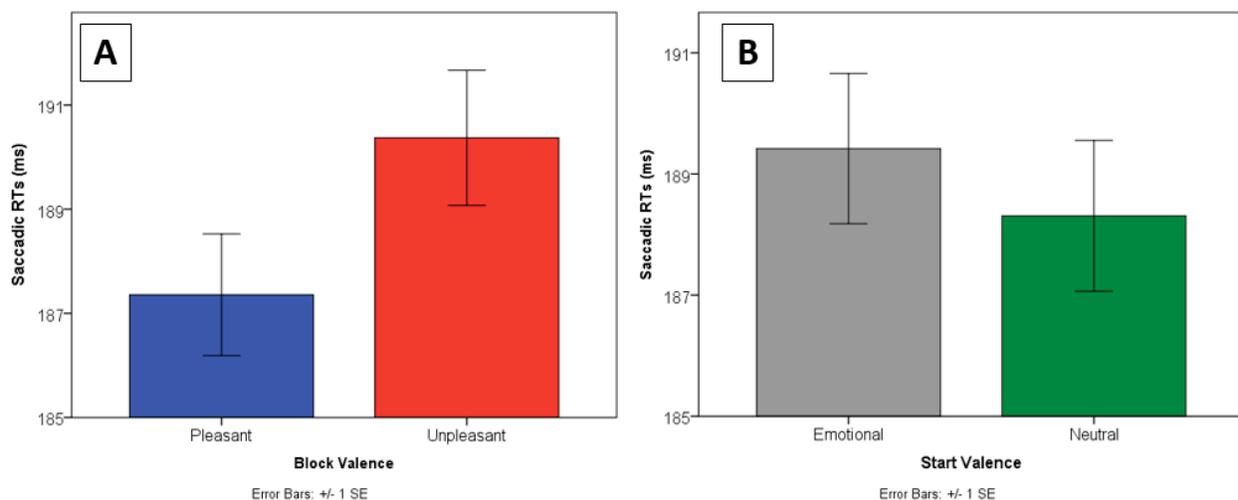
We mainly focused on RT data but additional analyses of accuracy data were also conducted. For the RT analysis, repeated-measures analyses of variance (ANOVAs) on RT and accuracy rate data were determined as a function of Block Valence (2 levels: Positive, Negative) x Start Valence (2 levels:

Emotional, Neutral) x End Valence (2 levels: Emotional, Neutral). We used an alpha level of 0.05 for all statistical tests.

## RESULTS

*Saccadic Reaction Times (RTs)*. An analysis of RTs yielded a significant main effect of Block Valence (Figure 4.2, A),  $F(1, 27) = 4.85$ ,  $p = .036$ ,  $\eta^2_p = .152$ , indicating slower saccadic RTs in the blocks with negative stimuli (190.37 ms) compared to those with positive stimuli (187.36 ms). A significant main effect of Start Valence (Figure 4.2, B) was also found,  $F(1, 27) = 8.67$ ,  $p = .007$ ,  $\eta^2_p = .243$ , indicating that participants were slower to disengage from emotional (189.42 ms) compared to neutral stimuli (188.31 ms). No main effect of End Valence factor was detected,  $F(1, 27) = 1$ , nor was there any interaction between the three factors.

*Accuracy*. The main effect of End Valence reached significance,  $F(1, 27) = 5.72$ ,  $p = .024$ ,  $\eta^2_p = .17$ , suggesting a greater accuracy when the movement was directed toward emotional (74%) compared to neutral (73%) stimuli. No other main effects or interactions were detected.



**Figure 4.2.** Results. (A). The saccadic response was slower in the two experimental blocks with negative and neutral pictures compared to the blocks with positive and neutral pictures. (B). The latency of the saccadic response was longer when the eye movements started from an emotional compared to neutral stimulus. RT = reaction time. Error bars denote the standard within-subject error term.

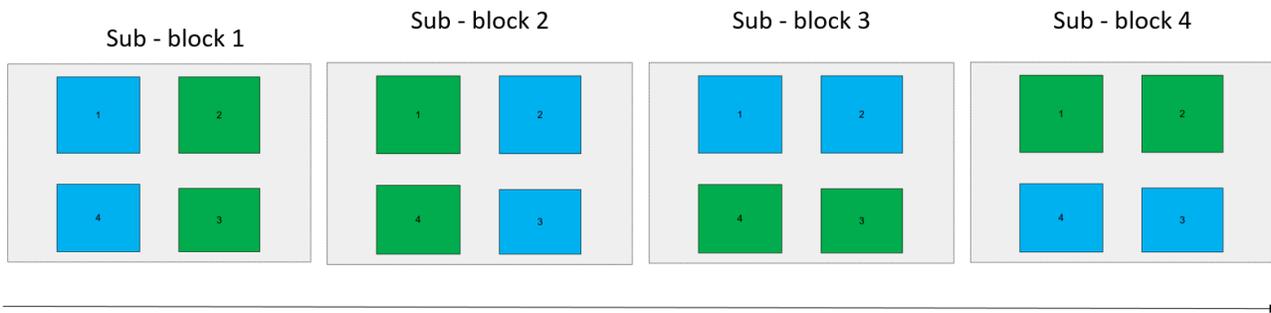
## EXPERIMENT 5, SUMMARY

The main findings of Experiment 5 are that the saccadic response is slowed down in the negative context, compared to the positive one, and when the saccadic movements start from emotional compared to neutral stimuli. The slower response in the unpleasant compared to the pleasant blocks, suggests a saccadic response pattern in line with the approach-avoidance hypothesis: when the approach behavior required by the task took place in a situation in which the probability of going toward a negative (vs. positive) stimulus was 50%, a general reduction in speed in the saccadic response was observed. This effect, that is, a slower response when the movement starts from an emotional stimulus, suggested that disengagement from emotional stimuli has a higher attentive cost compared to the disengagement from neutral stimuli (Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008). Interestingly, the valence of the stimuli to which the movement is directed does not impact the rapidity of the saccadic response. A possible interpretation of this result is that the dynamic nature of our task and the introduction of the emotional stimuli as a starting point for the movements weakens the emotional advantage of the emotional stimuli suggested by Calvo's studies (e.g., Nummenmaa et al., 2009). However, as suggested by the presence of a greater accuracy when the movement goes toward emotional compared to neutral stimuli, and in line with past studies, emotional significance, or at least a gist of affective valence, is perceived when the stimulus is still

outside foveal vision. Therefore, in a further experiment we will attempt to shed more light on the nature of the early attentional enhancement for emotional stimuli.

## Experiment 6: The effect of expectations on the saccadic response

In Experiment 5, we found a generic slowdown of the saccadic response in the unpleasant blocks and a slowdown when the saccadic movement started from emotional compared to neutral stimuli (disengagement effect). In this experiment, the probability that a neutral or an emotional (pleasant or unpleasant, based on the blocks) stimulus would follow the presentation of a neutral (or an emotional) stimulus was 50%. In other words, in Experiment 5 there was no systematic alternation between a neutral and emotional content nor between a content and a spatial position. However, there are many situations in which a spatial location is associated with an emotional content. For example, we could encounter a stream of congruent stimuli or a specific stimulus content that creates a context. This means that, in our daily attempt to scan the world around us, we could have expectations, based on prior knowledge, of what we are going to see. In Experiment 6, we used the same type of instructed saccade task, but this time participants were instructed as to the content that might appear in each specific position of the space before each experimental block (Figure 4.3). As in Experiment 5, we tested the hypothesis that saccadic behavior might be related to a valence-specific pattern (approach-avoidance vs. negativity bias) or to the emotional significance. The novelty of the present experiment lies in the fact that we tested the effects that expectations might have on saccadic behavior.



**Figure 4.3.** An example of one of the experimental sequences: the blue squares represent the positions associated with emotional contents, and the green ones represent the positions associated with neutral contents. During the 4 sub-blocks reported here, the hemifield associated with the emotional content changed across the blocks.

## METHOD

### Participants

Twenty-eight participants took part in Experiment 6 and provided written informed consent. Data from two participants were excluded because of poor performance (accuracy below 50%). Thus, the results reported here are based on data collected from 26 participants, ranging from 19 to 25 years old.

### Task and Data Analysis

The same stimuli and the same task used in Experiment 5 were replicated here. The only exception was in the block arrangements and the instructions. The experiment was divided into two main parts: in the first half of the experiment only pleasant and neutral stimuli were presented, while in the second half only unpleasant and neutral stimuli were presented (the order was counterbalanced between participants). Overall, a total of 1024 trials (movements) were performed in the entire

experiment, but this time each half of the experiment (pleasant and unpleasant) was divided into 4 sub-blocks and in each sub-block the association between a spatial position and an emotional content changed, in order to associate each hemifield with a specific content (see Figure 4.3). Two sequences were used to associate the blocks with a specific content: 1) left → right → top → bottom, and 2) top → bottom → left → right. Before each sub-block, written instructions appeared on the monitor, signaling which hemifield would be associated with the emotional content and which with the neutral content in the subsequent sub-block.

The order of the pleasant and unpleasant blocks in the first and second halves, as well as the sequences used to pseudorandomize the association of the hemifield with the emotional content, were balanced across participants. In total, 1024 movements (trials) were performed. The statistical design, as well as the number of trials per condition, were the same as those in Experiment 5, that is: 8 conditions [Block Valence (2 levels: Positive, Negative) x Start Valence (2 levels: Emotional, Neutral) x End Valence (2 levels: Emotional, Neutral)], each one characterized by 128 trials.

## RESULTS

*Saccadic Reaction Times (RTs).* A significant main effect of Start Valence was also found,  $F(1, 25) = 15.11$ ,  $p = .001$ ,  $\eta^2_p = .377$ , indicating that the participants were slower to disengage from emotional (184.5 ms) compared to neutral stimuli (182.81 ms). No main effect of the Block Valence or End Valence factor was detected, nor did the interaction between the three factors reach significance.

*Accuracy.* The main effect of Start Valence approached significance,  $F(1, 25) = 3.68$ ,  $p = .067$ ,  $\eta^2_p = .128$ , suggesting a greater accuracy when the movement starts from emotional (81%) compared to neutral (79%) stimuli. No main effects nor interactions were detected.

## **EXPERIMENT 6, SUMMARY**

In Experiment 6 we found a disengagement effect in the response time indicating that the saccadic movement slows down when it starts from an emotional compared to a neutral picture. This pattern did not differentiate positive and negative stimuli, suggesting that there is a cost in disengaging from high-arousing emotional stimuli that is not related to higher disengagement from negative stimuli (negativity bias hypothesis) or faster disengagement from negative stimuli (approach-avoidance hypothesis). The accuracy pattern suggests that the saccadic response might be more accurate when the movement starts from emotional stimuli compared to neutral stimuli (81% vs. 79%, respectively). Overall, however, it seems that expectation did not impact the saccadic programming. Even when participants know what type of content might appear in a specific spatial position, the saccadic response is not influenced by previous knowledge. One possible interpretation of this effect is that, even when we know what type of content is going to appear in a specific position, it is the irrelevance of the content for the actual task (instructed saccades) that prevents the saccade programming from being impacted.

### **Intermediate Summary: Evaluation of emotional stimuli in a dynamic task**

The main results of Experiments 5 and 6 support the idea that disengagement from emotional stimuli, compared to disengagement from neutral stimuli, slows down the saccadic response in a task that requires the subject to continuously scan the visual scene according to approach behavior. The dynamic nature of our instructed saccade task allowed us to highlight important key aspects related

to the approach behavior regarding emotional significant scenes. This effect is strong, both when we do not know what type of content might appear in the subsequent position (Experiment 5) and when we know what is going to happen next (Experiment 6). Interestingly, our data suggested that negative, compared to positive, information seems to have a greater impact only in the condition in which we cannot predict what the content of the subsequent stimulus will be; in fact, as suggested by the findings of Experiment 5, the saccades performed in the block with negative (and neutral) stimuli induced a slowdown of the saccadic response according to approach-avoidance behavior. In this condition, the approach behavior required by the task is significantly delayed compared to the approach toward positive and negative stimuli in the pleasant blocks. As far as accuracy is concerned an interesting pattern emerges in Experiments 5 and 6: while in Experiment 5 the accuracy level was higher when the saccades were directed toward emotional stimuli, these effects did not occur when participants were instructed to expect a specific content in a different spatial position of the visual scene (Experiment 6). One possible interpretation of our results is that since the emotional content anticipated by participants was irrelevant to the task, it did not influence saccadic programming.

## **CONCLUSIONS**

To summarize the results of Experiments 5 and 6, the dynamic nature of the instructed saccade task that we used allowed us to shed light on some aspects of the saccadic response. Our data suggested that, when we are engaged in the exploratory behavior that allows us to evaluate our environment, it takes us longer to disengage from stimuli that hold an emotional valence and to move our attention toward other stimuli. When the target of our saccadic movement is an emotional stimulus, our

movement seems to be more accurate compared to when the target is neutral, but there is no advantage in terms of response latency. This response pattern seems to work only when there is a 50% probability that the upcoming stimulus will have an emotional valence. However, when we are able to predict what will happen, the only effect is a slowing down in the disengagement from the current stimulus; the valence of the upcoming stimulus or the context in which it is presented do not have any effect on the saccadic program.

# Chapter 5

## General Discussion

Without a doubt, efficient selection of affectively significant visual stimuli in our environment is essential for our survival and well-being. The present work aimed to extend the literature on evaluation by providing a systematic investigation of the physiological and subjective correlates of this process, while emphasizing one of the most important aspects of the emotional response, that is, the emotional significance.

Arousal plays a central role in the emotional response, as stimuli are characterized by different levels of emotional significance. Accordingly, our visual system should allow for fast and efficient evaluation and selection of significant cues regardless of their valence. Throughout this work, we have considered the basic positive versus negative affective valence in our investigation of evaluation and attentional prioritization of affective stimuli. Within this framework, we questioned whether basic evaluation of affective stimuli is biased toward a specific valence category (especially by negative valence) or by the relevance of affectively significant information. Specifically, we focused on different indexes of the evaluative process: self-report of the affective states, EEG response (indexed by the Late Positive Potential and by the Alpha- desynchronization), attentive capture, and saccadic behavior. In the following sections, we will give a summary of the results concerning these aspects of investigation.

## The Motivational Gradients

The goal of the first two experiments was to compare the appetitive and defensive motivational gradients described by subjective and physiological indexes (both central and peripheral) of the emotional response. In order to test whether the differences between the motivational gradients might define functional differences, that is, the positivity offset and the negativity bias, we also investigated the temporal stability of the neural response (LPP and Alpha-ERD) to emotional stimuli. The findings showed that the motivational engagement gradients for appetitive and aversive stimuli do not differ when peripheral (skin conductance changes) and central (LPP and Alpha-ERD) indexes of the emotional response are considered, while the subjective evaluations suggested a steeper negative gradient.

Parallel to previous studies, the subjective evaluations of emotional stimuli varying in emotional arousal show a steeper negative gradient not only with pictures (Ito, Cacioppo, & Lang, 1998), but also with words or sounds (Bradley & Lang, 1999a,b), instrumental music (van Oyen Witvliet & Vrana, 1996) and films (Detenber, Simons, & Bennet, 1998); altogether, the data suggest a common organization for these perceptual stimuli. Although the subjective evaluation of emotional stimuli is used as an index of emotional engagement (Cacioppo et al., 1997), these responses are executed after a sequence of processing stages following the actual engagement of the motivational systems, and several factors, such as sociocultural differences, might affect the subjective responses. This hypothesis is further supported by the results regarding the emotional gradients described by autonomic changes. While previous studies only used subjective measures of arousal evaluation, we

also used skin conductance changes as a measure of physiological arousal. Our results suggest that the motivational gradients described by a physiological measure of emotional significance do not differentiate the appetitive and the defensive systems.

By using more temporally proximal measures of the evaluative process, that is, the LPP and the Alpha-ERD, we found that the motivational systems do not functionally differentiate positivity and negativity. In previous studies, the emotional modulation of the LPP in response to pictures of different emotional contents was used to examine attentional engagement and the activation of the motivational systems as a function of emotional significance (Cuthbert et al., 2000; Schupp et al., 2004; De Cesarei & Codispoti, 2006, 2011; Ferrari et al., 2015). However, previous studies investigated the affective modulation of the LPP by comparing the response to high-arousing pleasant (erotica) and unpleasant (mutilation) pictures, precluding the possibility of investigating the functional differences in the motivational gradients. Moreover, the limited number of stimuli used in the studies focusing on the affective modulation of the LPP with different emotional contents (Cuthbert et al., 2000; Schupp et al., 2004) restricted the possibility of investigating the functional differences between the motivational gradients for specific contents.

The physiological data of Experiments 1 and 2 are pertinent for at least two reasons. First, we can argue that the overlap in the appetitive and the defensive gradients described by the physiological response, but not by the subjective response, is unrelated to the differences between the task in Experiment 1 (evaluative categorization) and that in Experiment 2 (free-viewing); in fact, the skin conductance changes and the EEG response showed a similar modulation of the emotional response even if the tasks of the two experiments were different.

The present studies (Experiment 1 and 2) extend previous results by showing that the appetitive and defensive gradients do not functionally differentiate positivity and negativity. Additionally, the present study suggested that the Alpha-ERD shows a similar modulatory pattern observed in the LPP: the Alpha varies as a function of arousal, but does not functionally distinguish between positivity and negativity, as suggested by the overlap between the appetitive and defensive gradients. The present results parallel a recent study (De Cesarei & Codispoti, 2011) in which a similar modulatory pattern of the LPP and Alpha-ERD was observed as a function of emotional contents. In accordance with studies that suggested an enhanced cortical excitability and engagement in stimulus processing (Cooper, Croft, Dominey, Burgess, & Gruzelier, 2003; Klimesch, 1999; Klimesch, Sauseng, & Hanslmayr, 2007; Pfurtscheller, 2003; Pfurtscheller et al., 1996; Sauseng & Klimesch, 2008), the present studies suggest a higher activation of visual processing areas that are possibly associated with perceptual enhancement. Interestingly, the literature that focused on the specific functions of the alpha band recently suggested that the EEG alpha does not originate from idle brain regions (Pfurtscheller et al., 1996); the alpha is related to active inhibition rather than passive inactivity (Foxe and Snyder, 2011; Jensen & Mazaheri, 2010; Klimesch, 2012; Klimesch et al., 2007; Pfurtscheller, 2003; Uusberg et al., 2013). Contrasting evidence has been reported in the literature regarding the role of Alpha-ERD: While De Cesarei and Codispoti (2011) found a larger posterior alpha ERD for more emotionally-arousing images, Aftanas and colleagues found exactly the opposite relationship (2002; 2004). It has been proposed that both findings could reflect an increased inhibition of affect-irrelevant brain processes induced by motivated attention (Uusberg et al., 2013). In principle, significant information can be highlighted in the brain by disinhibiting the relevant as well as inhibiting the irrelevant representations; at a neural level, these shifts should result in a reduced and increased regional alpha

synchrony of local field potentials, respectively (Klimesch et al., 2007). The outcome on the scalp is less clear due to spatial mixing of different source signals impinging on each electrode. The present experiments indicate that the Alpha power parametrically decreases as a function of arousal. Furthermore, the emotional modulation of the Alpha band in these experiments suggests that the emotional arousal is associated with a greater Alpha decrease that may be associated with a greater perceptual engagement, and the hypothesis that this effect might be related to mixing sources of signals seems to be unlikely.

The debate on the functional role of the Alpha band perfectly describes a methodological issue that arose in the studies that used a categorical approach. For example, some results in the past that supported the negativity bias merely compared the LPP to two positive and two negative stimuli (Ito et al., 1998). Even in clinical psychology, the dimensional instead of the categorical approach has recently been highlighted. The National Institute of Mental Health (NIMH) has begun a new program of research support (Insel & Cuthbert, 2009; Kozak & Cuthbert, 2016) called the Research Domain Criteria (RDoC) with the goal to develop new ways of classifying mental disorders based on dimensions of observable behavior and neurobiological measures.

Recently, Lang and Bradley started a research project focused on the dimensional approach to describe the physiological reaction of patients across anxiety diagnoses (Lang and McTeague, 2011; Lang, McTeague, & Bradley, 2014; 2016; McTeague, 2016; McTeague et al., 2009; 2010; 2012). With the heuristic outlined by the Research Domain Criteria (RDoC) initiative as a starting point, an exploratory transdiagnostic analysis has been presented by the authors, based on a sample of 425 treatment-seeking patients from across the spectrum of DSM-IV anxiety diagnoses (e.g., Post Traumatic Stress Disorder with a single or multiple stressful events, Generalized Anxiety, single or

multiple phobias). Using a composite index of startle reflex and heart rate reactivity during idiographic fear imagery for each patient, a defensive dimension was defined, ranking patients from the most defensively reactive to the least reactive and then creating five groups of equivalent size. Subsequent analyses showed significant parallel trends of diminishing reactivity in both electrodermal and facial electromyographic reactions across this defensive dimension. Negative affectivity, defined by questionnaire and extent of functional interference, however, showed consistent inverse trends with defensive reactivity: as reports of distress increased, defensive reactivity was increasingly attenuated. Notably, representatives of each principal diagnosis appeared in each quintile, underlining the reality of pronounced within-diagnosis heterogeneity in defensive reactivity. Thus, the use of the continuous dimension rather than single categories might be of greater advantage in both basic and clinical research.

The present results are in contrast with the idea that negative stimuli have a greater adaptive value compared to positive stimuli. In fact, if that were the case, one could expect a greater temporal stability in the brain response to negative compared to positive stimuli. Consistent with a previous study that suggested a high-temporal stability in the LPP response as a function of stimulus repetition (Codispoti, Ferrari, Bradley, 2007), the present data showed a greater temporal stability of both the appetitive and defensive gradients, suggesting that LPP reflects the emotional significance of the stimuli.

Altogether, the results of Experiments 1 and 2 suggest that the evaluation of emotional stimuli depends on their significance. In fact, no functional differences (e.g., steeper negative gradient) were found in the physiological responses (LPP, Alpha-ERD, Skin conductance changes) describing the evaluative process, results that were further corroborated by the high-temporal stability of both

appetitive and defensive gradients. However, a steeper negative gradient was found in the evaluation of the subjective states elicited by emotional pictures. Because our visual system serves the adaptive function of identifying potential threats and rewards, one interpretation of our findings is that the motivational engagement in early stages of information processing does not differentiate positivity and negativity. In early stages, as indexed by LPP and Alpha-ERD, motivational engagement is strictly related to emotional significance. Only in later stages does the difference in evaluation emerge, as shown by a steeper negative gradient found in subjective reports. This might suggest that the differences between positivity and negativity appear at later stages of emotional processing and are probably related to cultural rules of emotional expression.

### **Attentive Capture of Multiple High-Arousing Stimuli**

Once we evaluate significant stimuli, which is important for our well-being and continued survival, attentional resources are allocated to the emotional stimuli in order to process the information that allows us to act appropriately. In Experiments 3 and 4 we were interested in investigating the effects of attentive capture regarding emotional stimuli that compete for attentional resources simultaneously (Experiment 3) or in rapid alternation (Experiment 4). The main goal was to test whether a negativity bias appears when appetitive and aversive stimuli compete for attentional resources, that is a greater behavioral interference induced by pairs of high-arousing stimuli of opposite valences. In Experiment 3 we found that the interference effect induced by emotional stimuli parametrically varies as a function of the number of emotional stimuli in the visual scene. First, we observed that two high-arousing distractor stimuli of the same valence (pleasant or unpleasant) elicited a greater interference compared to one high-arousing stimulus, suggesting that parametric

increases in distractor intensity led to parametric changes in behavioral interference. More importantly, when pleasant and unpleasant task-irrelevant stimuli simultaneously competed for resources, we observed that the interference effect was the same as that of the two pleasant or two unpleasant distractor stimuli. Similar results were obtained from Experiment 4, in which emotional primes and targets elicited a greater interference effect compared to neutral distractors, but the interference effect on the targets was not modulated by the valence of the preceding primes (that is, no interaction between prime and target was detected).

RTs are often used to measure attention to emotional stimuli (Calvo et al., 2015; Ferrari, Bruno, Chattat, Codispoti, 2017; Padmala & Pessoa, 2014), and past studies have suggested that attentional engagement is related to stimulus significance (Buodo, Sarlo, Palomba, 2002; De Cesarei & Codispoti, 2008). However, while in past studies emotional significance was defined in terms of emotional contents (low-arousing stimuli such as pictures of babies vs. high-arousing stimuli such as erotica), in our experiments the emotional significance of the visual scene was manipulated by using a combination of multiple neutral and arousing stimuli.

The findings of Experiment 3, in which distractors were presented simultaneously, extend the results of the experiments that in the past few years have investigated the effects of categorization of multiple natural scenes. By using behavioral and ERP indexes, Rousselet and colleagues (Rousselet, Fabre-Thorpe, Torpe, 2002) suggested that humans are faster at responding to two simultaneously-presented natural images than to a single image. The result of Rousselet's study suggests that even complex natural images can be processed in parallel. Starting from this assumption, we can safely conclude that the results of Experiment 3 are not due to differences in the terms of processing, but are mainly driven by the emotional significance of the stimuli that constituted the visual scene.

Moreover, the impact of the number of stimuli within the visual scene on the ongoing behavior is more interesting in the light of the fact that not every type of arousal manipulation in past studies found a modulation of the behavioral interference effect. The stimulus relevance may vary in terms of content and contextual factors, such as the distance from the observer. De Cesarei and Codispoti (2008) manipulated the size of the pictures to study the effects of saliency, described in terms of distance from the observer to the emotional stimuli. They found that the attentive capture was modulated by the content of the stimuli (see also Buodo et al., 2002; Calvo et al., 2015), but not by stimulus size, suggesting that attentive capture relies on information that is sufficient to allow a categorization of picture content.

Similarly to Experiment 3, in Experiment 4 behavioral interference was found to be related to the emotional significance of both primes and targets. Even though the task was similar to the affective priming paradigm in terms of trial arrangement, it was not an evaluative task; nor was the valence of the stimuli expected. The former has been widely investigated; when participants are engaged in an evaluative categorization task they are faster at evaluating a target stimulus if a previously presented prime has the same valence, compared to the condition in which a prime stimulus of the opposite valence is shown (Fazio et al., 1986). To extend the findings of semantic-priming literature, the affective congruency effect has been explained in terms of valence-based spreading of activation (Fazio et al., 1986). However, the affective congruency between prime and target is confounded with the compatibility of the response that is associated with these stimuli, and the affective priming task ends up being similar to a response-priming paradigm (Wentura & Degner, 2010). According to a response competition account (Klauer et al., 1997; Wentura, 1999), processing of the prime stimuli elicits a behavioral response tendency that matches that of the target in the affectively congruent

pairs, but is in conflict with the incongruent prime-target pairs. This is obviously not the situation in our experiment, in which the task in which participants were engaged, a visual search task, was not related to valence. Moreover, the task-irrelevant status of our emotional stimuli does not match the hypothesis that the affective congruency effect in the priming studies occurs only when the valence of the stimuli is expected. In fact, in a series of experiments, Spruyt and colleagues (Spruyt et al., 2007, 2009, 2012) suggested that the affective priming effect is related to the attentional focus, suggesting that the facilitated encoding of affectively congruent information occurs if the valence of the prime was expected. This hypothesis was defined by the authors as “attention-dependent affective/semantic encoding”. This proposal obviously does not correspond with Experiment 4 of our study, in which the emotional stimuli were not expected.

Altogether, our findings are consistent with the hypothesis that attentional capture is prompted in a processing stage in which stimuli are evaluated in terms of significance, regardless of their valence, even when multiple valenced stimuli compete for attentional resources. Several studies indicate that stimulus significance is a critical factor in both orienting and emotion (Bernstein, 1979; Bradley, 2009; Codispoti, De Cesarej, Biondi Ferrari, 2016; Donchin 1981; Maltzman, 1979).

Our results in the visual modality are further supported by a recent series of studies in the auditory modality. Folyi and Wentura (2017), by using a set of natural emotional sounds, showed that affective information of natural emotional sounds can be extracted rapidly (i.e. after a few hundred ms of exposure) and in an unintentional fashion. These results were further replicated recently by the same group: in order to avoid perceptual confounds due to the types of sounds, the authors induced valence experimentally during a learning phase by assigning positive, negative, and neutral valences to tone-frequencies in a balanced design. In a subsequent test phase, in which these tones were

entirely task-irrelevant, the EEG was recorded; the data obtained suggests a general relevance of the valenced tones that governs early attentional processes (Folyi, Liesefeld, & Wentura, 2016), without any specific advantage shown by the negative over the positive stimuli.

Because our perceptual system serves the function of identifying potential threats and rewards, it is highly adaptive to the evaluation of all incoming stimuli regardless of their valence. Our data support this hypothesis, suggesting that attentive capture is strictly related to the emotional significance of the stimuli.

### **Evaluation of Emotional Stimuli in a Dynamic Task**

One interpretation of the behavioral interference found on primes in the Experiment 4, is that the slow down might be due to a disengagement effect from the emotional prime, compared to the neutral ones. In Experiments 5 and 6 we made another step in this direction by directly investigating the effects of disengagement in an instructed saccade task that required the participants to continuously scan the visual scene. In these experiments, we tested the idea that saccadic approach behavior might be modulated by a valence-specific effect (negativity bias vs. approach-avoidance).

The results can be summarized as follows: (1) the saccadic response is delayed when the movement starts from an emotional compared to a neutral stimulus, regardless of the expectations related to the next stimulus, suggesting a cost in terms of response time to disengage from significant stimuli; (2) the saccadic response is more accurate toward a significant approaching stimulus only when there are no expectations as to the upcoming contents; (3) the saccadic response is generally delayed in a negative compared to a positive context only when the participant has no expectations regarding the upcoming content, in accordance with the approach-avoidance hypothesis.

Previous studies that investigated the impact of extrafoveal stimuli on saccadic programming mostly focused on the contents of the “target” stimulus, that is, the stimulus toward which the movement is directed. These studies showed a greater attentional capture and a selective orienting to extrafoveal emotional scenes compared to neutral ones (Calvo et al., 2008; Humphrey, Underwood, & Lambert, 2012; McSorely & van Reekum, 2013; Niu, Todd, & Anderson, 2012; Nummenmaa et al., 2006, 2009), suggesting that extrafoveal emotional stimuli can be perceived when they are presented outside the focus of attention and then guides saccadic behavior. Experiments 5 and 6 of our study extended the results of these studies by considering the disengagement component of spatial attention (Posner, Inhoff, Friedrich, & Cohen, 1987). Moreover, while previous studies used “static” tasks, with a long ITI between the trials, in our experiments we used a dynamic task in which the stimuli were presented in a continuous stream. Under these specific conditions, the only valence-specific effect detected was in Experiment 5, in which a general slowdown was found in the negative context compared to the positive context. However, no difference between pleasant and unpleasant stimuli were found in terms of disengagement, suggesting that the emotional significance (arousal) of the stimuli is the key factor in this component of spatial attention (see also Vogt, De Houwer, Van Damme, & Crombez, 2008).

In the engagement component, however, we did not find a strong effect of emotional stimuli in the attentive capture. The only hint that the target stimuli may have an impact on the saccades is in Experiment 5, in which a greater accuracy was present when the movement shifted toward emotional compared to neutral stimuli. This suggests that the emotional significance, or at least a gist of affective valence, is perceived when the stimulus is still outside foveal vision. However, no effects were detected on saccade latency in either Experiment 5 or 6.

There are two main differences between our experiments and the classical tasks used in most of the previous studies. First, in our experiments the stimuli were presented in a continuous stream with a short gap (100ms) between the pictures, while in previous studies there was usually a variable ITI between the stimuli that varied from 0.5 to 2 seconds ( eg., Calvo & Nummenmaa, 2007; Calvo, Rodriguez-Chinea, Fernandez-Martin, 2015, Calvo, Gutierrez-Garcia, del Libano, 2015). The difference in the timing of stimuli presentation might also explain the difference in terms of latency between our experiments and previous studies; while in our experiments saccadic latency was around 200 ms, in Calvo's studies the saccadic response was above 500 ms (e.g., Calvo, Rodriguez-Chinea, Fernandez-Martin, 2015, Calvo, Gutierrez-Garcia, del Libano, 2015). One interpretation of the present findings is that, at this latency (200 ms), the target stimuli might not have an impact on attentive capture.

Second, in our experiments the movements could be horizontal or vertical, while the saccadic behavior studied by Calvo and colleagues usually concerned horizontal movements (Calvo, 2006; Calvo & Lang, 2005; Calvo et al., 2015; Fernandez-Martin & Calvo, 2015).

The main difference between Experiments 5 and 6 was the anticipation of the upcoming content in specific spatial positions. The literature on emotional processing offers important information regarding the impact of expectation in stimulus processing. Classical conditioning studies have shown that emotional reactions to an aversive stimulus are dampened when a cue reliably signals its occurrence, suggesting that prior knowledge can attenuate stimulus aversiveness through expectation (Dufort & Kimble, 1958; Kimble & Ost, 1961; Lykken & Tellegen, 1974). More recently, Bradley and Lang (Sege, Bradley, & Lang, 2014; 2015) showed a similar pattern in the startle reflex modulation during picture viewing: when unpleasant emotional pictures were preceded by a cue that signaled their occurrence, no potentiation of the defensive response (indexed by the startle reflex) was

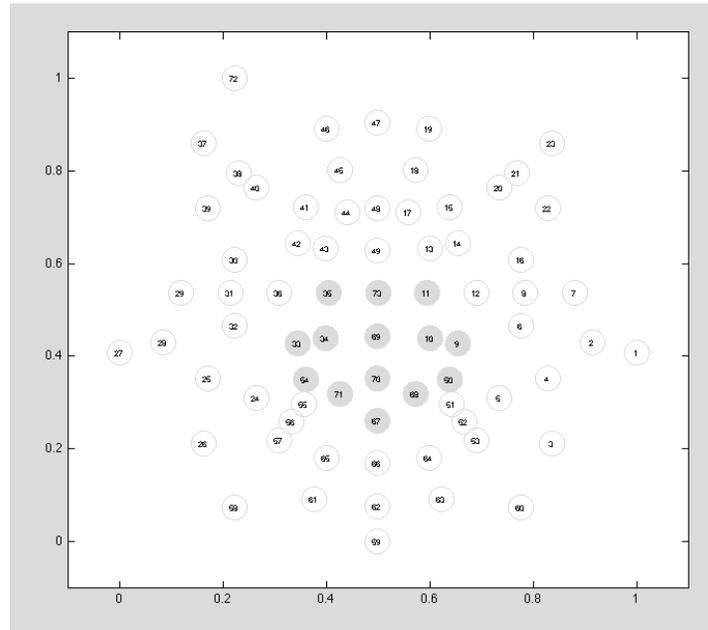
detected, and the elicited defensive response did not differentiate neutral and negative stimuli. However, in the most recent study (Sege, Bradley, & Lang, 2016), the authors indicated that cueing a positive stimulus does not impact the response attenuation to positive contents, suggesting that cues elicit an anticipatory coping process that is specific for aversive stimuli. In fact, as conditioning researchers suggest, preparatory coping might involve an increase in sensory thresholds that reduces the perceived intensity of an aversive stimulus such as a shock (Lykken & Tellegen, 1974). Hence, it seems that the close relationship between an aversive cue and the stimulus is crucial for coping, and might explain why repeated exposure to an unsigned aversive picture does not reduce startle potentiation even with massive repetitions (Ferrari et al., 2011). As Sege and colleagues suggested (Sege, Bradley, & Lang, 2014; 2015), although massed repetition might be expected to induce active anticipation, the question of whether the upcoming scene will remain the same or change still remains uncertain even in a massed repetition context, perhaps making anticipatory coping less useful. In addition, explicit cueing could engage a specific preparatory process that facilitates coping with the aversive event when it occurs, a preparatory process that is not engaged by mere repetition. The fact that startle modulation during pleasant picture viewing was not altered by prior information regarding specific content is consistent with a hypothesis that coping is particularly important for aversive, but not for appetitive, events. In Experiment 6 of our study, the anticipatory coping might be a possible reason for the disappearance of the saccadic slowdown induced by the negative context in Experiment 5.

## **Conclusions**

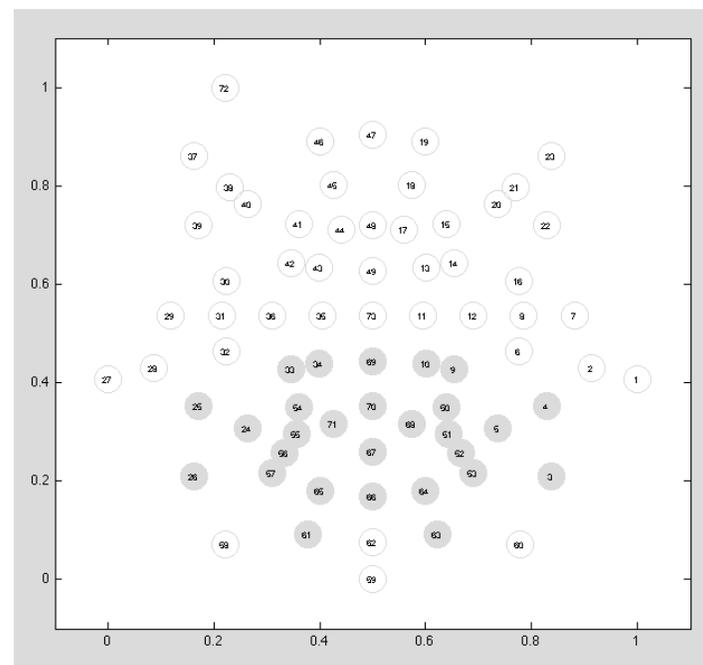
In the present work, we investigated affective evaluation of visual stimuli and its interplay with subjective responses, physiological responses, and visual attention, while highlighting the importance of the dynamic aspects of the evaluative process. Our first line of research provided evidence that the evaluation is closely related to the emotional significance of the scene and does not differentiate positivity and negativity at early stages of the evaluation, while the subjective responses suggested a greater emotional significance assigned to negative compared to positive stimuli. The second line of research demonstrated that affectively significant stimuli engage attention as a function of the arousing stimuli within the visual scene, regardless of their valence, even when positive and negative stimuli compete for attentional resources. In the third line of research, we found that the rapid evaluation of emotional stimuli might be impaired when a stream of stimuli occurs, because the attentional resources are usually engaged in the current stimulus and we are not able to process quick changes in our environment efficiently. Moreover, we found weak evidence supporting the idea that being able to predict the occurrence of an emotional stimulus in a specific spatial position may override the emotional impact on the evaluation of emotional stimuli. Altogether, our results suggest that when we encounter a new stimulus we have to evaluate it and allocate attention to it in order to act appropriately. In the early stages of information processing, this process does not differentiate positivity and negativity, but, rather, depends on the emotional significance of the stimuli. No advantages, in terms of attentional engagement and disengagement or physiological response, were detected for negative stimuli and their adaptive values. After all, even a system shaped to prioritize negative stimuli might be maladaptive in the long term. In fact, even though the evidence regarding this issue is weak, it seems that the possibility of anticipating the occurrence of a negative stimulus may reduce the motivational engagement toward the emotional stimuli in a negative context.

The evaluation of visual emotional stimuli has been described as a fast and highly efficient process. However, the fast detection and evaluation of a significant stimulus might suffer in the dynamic nature of our environment, in which multiple stimuli compete for attention but in which the limited amount of resources does not allow us to process and evaluate everything. We hope that future investigations into emotional evaluation will take into account the complexity of the environment that surrounds us.

# Note Section



**Figure 1.** The dark-gray circles show the sensors used in the scoring of the Late Positive Potential (LPP) in the Experiment 2.



**Figure 2.** The dark-gray circles show the sensors used to calculate the Alpha-Desynchronization (Alpha-ERD) in the Experiment 2.

comparison	Late Positive Potential (LPP)	Alpha-Desynchronization (Alpha-ERD)
Pleasant vs Neutral	t(23)= 12.89, p<.0001	t(23)= -9.04, p<.0001
Unpleasant vs Neutral	t(23)= 11.31, p<.0001	t(23)= 4.98, p<.0001
Pleasant vs Unpleasant	t(23)= 1.79, p=.087	t(23)= -3.94, p=.001

**Table 1.** The table shows the pairwise comparisons between the emotional and the neutral contents in the Late Positive Potential and the Alpha-Desynchronization of the Experiment 2.

# Bibliography

Acunzo, D.J., Henderson, J.M. (2011). No emotional "pop-out" effect in natural scene viewing. *Emotion*, 11(5), 1134-43.

Adelmann, P. K., & Zajonc, R. B. (1989). Facial efference and the experience of emotion. *Annual Review of Psychology*, 40, 249–280. <https://doi.org/10.1146/annurev.psych.40.1.249>

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (1994). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature*, 372, 669 – 672.

Aftanas, L.I., Varlamov, A.A., Pavlov, S.V., Makhnev, V.P., Reva, N.V., 2002. Time-dependent cortical asymmetries induced by emotional arousal: EEG analysis of event-related synchronization and desynchronization in individually defined frequency bands. *Int J Psychophys* 44 (1), 67–82.

Aftanas, L.I., Reva, N.V., Varlamov, A.A., Pavlov, S.V., Makhnev, V.P., 2004. Analysis of evoked EEG synchronization and desynchronization in conditions of emotional activation in humans: temporal and topographic characteristics. *Neuroscience and Behavioral Physiology* 34 (8), 859–867.

Alpers, G. W. (2008). Eye-catching: Right hemisphere attentional bias for emotional pictures. *Laterality*, 13, 158–178.

Alves, H., Koch, A., & Unkelbach, C. (2017). Why Good Is More Alike Than Bad: Processing Implications. *Trends in Cognitive Sciences*, xx, 1–11. <https://doi.org/10.1016/j.tics.2016.12.006>.

Armony, J. L., & Dolan, R. J. (2002). Modulation of spatial attention by fear-conditioned stimuli: an event-related fMRI study. *Neuropsychologia*, 40(7), 817–826.

Asgaard, G. L., Gilbert, D. G., Malpass, D., Sugai, C., & Dillon, A. (2010). Nicotine primes attention to competing affective stimuli in the context of salient alternatives. *Experimental and Clinical Psychopharmacology*, 18, 51–60.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzen-doorn, M. H. (2007). Threat-related attentional bias in anxious and non-anxious individuals: A meta-analytic study. *Psychological Bulletin*, 133(1), 1–24.

Beaver, J. D., Mogg, K., & Bradley, B. P. (2005). Emotional conditioning to masked stimuli and modulation of visuospatial attention *Emotion*, 67–79.

Berntson, G. G., Boysen, S. T., & Cacioppo, J. T. (1993). Neurobehavioral organization and the cardinal principle of evaluative bivalence. *Annals of the New York Academy of Sciences*, 702, 75-102.

Berridge, K.C. (1999). Pleasure, pain, desire, and dread: hidden core processes of emotion. In *Well-Being*, D. Kahnemann, E. Diener, and N. Schwarz, eds. (New York: Russell Sage Foundation).

Berridge, K.C. (2007). The debate over dopamine's role in reward: the case for incentive salience. *Psychopharmacology (Berl.)* 191, 391–431.

Blair, K. S., Smith, B. W., Mitchell, D. G., Morton, J., Vythilingam, M., Pessoa, L., et al. (2007). Modulation of emotion by cognition and cognition by emotion. *Neuroimage*, 35, 430 – 440.

Bradley MM. (2009). Natural selective attention: orienting and emotion. *Psychophysiology*. 46(1), 1-11.

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion*, 1 (3), 276.

Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (1996a). Picture media and emotion: Effects of a sustained affective context. *Psychophysiology*, 33, 662– 670

Bradley, M. M., Drobles, D., & Lang, P. J. (1996b). A probe for all reasons: Reflex and RT measures in perception [Abstract]. *Psychophysiology*, 33 (Suppl.), S25

Bradley, M.M., & Lang, P.J. (1999a). Affective Norms for English Words (AVEW): Instructions manual and affective ratings. Technical report no. C-1, Center for Research in Pshychophysiology, University of Florida, Gainesville.

Bradley, M.M., & Lang, P.J. (1999b). International affective digitized sounds (IADS): Stimuli, instructions manual and affective ratings. Technical report no. B-2, Center for Research in Pshychophysiology, University of Florida, Gainesville.

Bradley, M. M., & Lang, P. J. (2007). Emotion and motivation. In J. T. Cacioppo, L. G. Tassinary, & G. Berntson (Eds.) *Handbook of Psy- chophysiology* (3rd ed, pp. 581–607). New York, NY: Cambridge University Press.

Briggs, K. E., & Martin, F. H. (2008). Target processing is facilitated by motivationally relevant cues. *Biological Psychology*, 78(1), 29–42. <https://doi.org/10.1016/j.biopsycho.2007.12.007>

Briggs, K. E., & Martin, F. H. (2009). Affective picture processing and motivational relevance: Arousal and valence effects on ERPs in an oddball task. *International Journal of Psychophysiology*, 72(3), 299–306.

Brooks, P., Young, A. W., Maratos, E. J., Coffey, P. J., Calder, A. J., Isaac, C. L., Mayes, A. R., Hodges, J. R., Montaldi, D., Cezayirli, E., Roberts, N., & Hadley, D. (1998). Face processing impairments after encephalitis: Amygdala damage and recognition of fear. *Neuropsychologia*, 36, 59 – 70.

Buchel C, Dolan RJ.(2000). Classical fear conditioning in functional neuroimaging. *Current Opinion in Neurobiology*, 10(2), 219–223.

Buchel C, Morris J, Dolan RJ, Friston KJ (1998). Brain systems mediating aversive conditioning: an event-related fMRI study. *Neuron*, 20:947–957.

Buodo, G., Sarlo, M., Palomba, D. (2002). Attentional Resources Measured by Reaction Times Highlight Differences Within Pleasant and Unpleasant, High Arousing Stimuli. *Motivation and Emotion*, 26(2), 123-138

Cacioppo, J. T., & Berntson, G. G. (1994). Relationship between attitudes and evaluative space: A critical review, with emphasis on the separability of positive and negative substrates. *Psychological Bulletin*, 115(3), 401–423.

Cacioppo J.T., Berntson G.G., Norris C.J., Gollan J.K. (2011). The evaluative space model: Functional structure and operating characteristics of the affect system. In: Van Lange P, Kruglanski A, Higgins ET, editors. *Handbook of theories of social psychology*. Sage Press.

Cacioppo, J. T., Crites, S. L., Jr., Berntson, G. G., & Coles, M. G. H. (1993). If attitudes affect how stimuli are processed, should not they affect the event-related brain potential? *Psychological Science*, 4, 108-112.

Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1997). Beyond Bipolar Conceptualizations and Measures: The Case of Attitudes and Evaluative Space. *Personality and Social Psychology Review*, 3–25.

Calder, A. J., Young, A. W., Rowland, D., Perrett, D., Hodges, J. R., & Etcoff, N. L. (1996). Facial emotion recognition after bilateral amygdala damage: Differentially severe impairment of fear. *Cognitive Neuropsychology*, 13, 699 – 745.

Calvo, M.G., Gutiérrez-García, A., Del Líbano, M.(2015). Sensitivity to emotional scene content outside the focus of attention. *Acta Psychol (Amst)*. 2015 Oct;161:36-44.

Calvo, M. G., & Lang, P. J. (2005). Parafoveal semantic processing of emotional scenes. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 502–519.

Calvo, M. G., & Nummenmaa, L. (2007). Processing of unattended emotional visual scenes. *Journal of Experimental Psychology General*, 136, 347–369

Calvo, M. G., Nummenmaa, L., & Hyönä, J. (2008). Emotional scenes in peripheral vision: Selective orienting and gist processing, but not content identification. *Emotion*, 8, 68–80.

Canli T, Zhao Z, Brewer J, Gabrieli JD, Cahill L. Event-related activation in the human amygdala associates with later memory for individual emotional experience. *J Neurosci*. 2000;20:RC99

Cardinal, R.N., Parkinson, J.A., Hall, J., and Everitt, B.J. (2002). Emotion and motivation: the role of the amygdala, ventral striatum, and prefrontal cortex. *Neuroscience Biobehavioral. Rev.* 26, 321–352.

Carlson, J. M., Beacher, F., Reinke, K. S., Habib, R., Harmon-Jones, E., Mujica-Parodi, L. R., & Hajcak, G. (2012). Nonconscious attention bias to threat is correlated with anterior cingulate cortex gray matter volume: A voxel-based morphometry result and replication. *NeuroImage*, 59(2), 1713–1718.

Carretié, L., Mercado, F., Tapia, M., & Hinojosa, J. A. (2001). Emotion, attention, and the “negativity bias”, studied through event-related potentials. *International Journal of Psychophysiology*, 41(1), 75–85.

Codispoti, M. De Cesarei,A., Biondi, S., & Ferrari, V. (2016). The fate of unattended stimuli and emotional habituation: Behavioral interference and cortical changes. *Cognitive,Affective, & Behavioral Neuroscience*, 16(6), 1063–73

Codispoti, M., Ferrari, V., & Bradley, M. M. (2006). Repetitive picture processing: Autonomic and cortical correlates. *Brain Research*, 1068, 213–220.

Codispoti M., Ferrari V., Bradley MM. (2007). Repetition and ERPs: Distinguishing early and late processes in affective picture perception. *Journal of Cognitive Neuroscience*. 19, 577-586.

Codispoti, M., Mazzetti, M., & Bradley, M. M. (2009). Unmasking emotion: Exposure duration and emotional engagement. *Psychophysiology*, 46, 731-738.

Codispoti M., De Cesarei A., & Ferrari V. (2012). The influence of color on emotional perception of natural scenes. *Psychophysiology*, 49(1), 11-6.

Cooper, N. R., Croft, R. J., Dominey, S. J., Burgess, A. P., & Gruzelier, J. H. (2003). Paradox lost? Exploring the role of alpha oscillations during externally vs. internally directed attention and the implications for idling and inhibition hypotheses. *International Journal of Psychophysiology*, 47, 65–74.

Crites S.L. Jr, Cacioppo J.T., Gardner W.L., Berntson, G.G. (1995). Bioelectrical echoes from evaluative categorization: II. A late positive brain potential that varies as a function of attitude registration rather than attitude report. *J Pers Soc Psychol*, 68(6), 997-1013.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology*, 52(2):95-111.

Dannlowski, U., Kersting, A., Lalee-Mentzel, J., Donges, U., Arolt, V., & Suslow, T. (2006). Subliminal affective priming in clinical depression and comorbid anxiety: A longitudinal investigation. *Psychiatry Research*, 143, 63–75

De Cesarei, A., & Codispoti, M. (2006) . When does size not matter? Effects of stimulus size on affective modulation. *Psychophysiology*. 43 (2), 207-15.

De Cesarei, A., Codispoti, M. (2008). Fuzzy picture processing: effects of size reduction and blurring on emotional processing. *Emotion*, 8(3), 352-63.

De Cesarei A., & Codispoti M. (2011a). Affective modulation of the LPP and alpha-ERD during picture viewing. *Psychophysiology*, 48, 1397–1404

De Cesarei, A., & Codispoti, M. (2011b). Scene identification and emotional response: which spatial frequencies are critical? *Journal of Neuroscience*. 31: 17052-17057.

Degner, J., & Wentura, D. (2010). Automatic prejudice in childhood and early adolescence. *Journal of Personality and Social Psychology*, 98, 356–374.

De Houwer, J., Teige-Mocigemba, S., Spruyt, A., & Moors, A. (2009). Implicit measures: A normative analysis and review. *Psychological Bulletin*, 135, 347–368.

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics. *Journal of Neuroscience Methods*, 134, 9–21.

Derryberry, D., & Tucker, D. M. (1994). Motivating the focus of attention. In P. M. Niedenthal & S. Kitayama (Eds.), *The heart's eye: Emotional influences in perception and attention* (pp. 167–196). San Diego, CA: Academic

Detember, B.H., Simons, R.F., & Bennett, G.G. (1998). Roll'em!: The effects of picture motion on emotional responses. *Journal of Broadcating and Electronic Media*, 42, 113-27.

Deuter, C.E., Schilling, T.M., Kuehl, L.K., Blumenthal, T.D., Schachinger, H. (2013). Startle effects on saccadic responses to emotional target stimuli. *Psychophysiology*, 50(10), 1056-63.

Dickinson, A., & Dearing, M. F. (1979). Appetitive-aversive interactions and inhibitory processes. In A. Dickinson & R. A. Boakes (Eds.), *Mechanisms of learning and motivation. a memorial volume to jerzy konorski* (p. 203-231). Hillsdale, NJ: Erlbaum.

Donchin, E. (1981). Surprise! . . . Surprise? *Psychophysiology*, 18, 493-513.

Dovidio, J. F., Evans, N., & Tyler, R. B. (1986). Racial stereotypes: The contents of their cognitive representations. *Journal of Experimental Social Psychology*, 22, 22–37.

Dufort, R. H., & Kimble, G. A. (1958). Ready signals and the effect of interpolated UCS presentation in eyelid conditioning. *Journal of Experimental Psychology*, 56, 1–7.

Ekman, P., Levenson, R. V, & Friesen, V. W. (n.d.). Autonomic Nervous System Activity Distinguishes Among Emotions. *Science*, 21(4616), 1208–1210.

Erthal, F. S., de Oliveira, L., Mocaiber, I., Pereira, M. G., Machado- Pinheiro, W., Volchan, E., & Pessoa, L. (2005). Load-dependent modulation of affective picture processing. *Cognitive Affective and Behavioral Neuroscience*, 5, 388–395.

Eves, F. F., Scott, E. J., Hoppé, R., & French, D. P. (2007). Using the affective priming paradigm to explore the attitudes underlying walking behaviour. *British Journal of Health Psychology*, 12, 571–585.

Fazio, R. H. (2001). On the automatic activation of associated evaluations: An overview. *Cognition & Emotion*, 15, 115–141.

Fazio, R. H., Jackson, J. R., Dunton, B. C., & Williams, C. J. (1995). Variability in automatic activation as an unobtrusive measure of racial attitudes: A bona fide pipeline? *Journal of Personality and Social Psychology*, 69, 1013–1027.

Fazio, R. H., & Olson, M. A. (2003). Implicit measures in social cognition research: Their meaning and uses. *Annual Review of Psychology*, 54, 297–327.

Fazio, R. H., Sanbonmatsu, D. M., Powell, M. C., & Kardes, F. R. (1986). On the automatic activation of attitudes. *Journal of Personality and Social Psychology*, 50, 229–238

Ferguson, M. J., & Bargh, J. A. (2003). The constructive nature of automatic evaluation. In J. Musch & K. C. Klauer (Eds.), *The psychology of evaluation: Affective processes in cognition and emotion* (pp. 169–188). Mahwah, NJ: Erlbaum.

Fernández-Martín, A., Calvo, M.G. (2016). Selective orienting to pleasant versus unpleasant visual scenes. *Cognition*, 155, 108-12.

Ferrari, V., Bradley, M. M., Codispoti, M., & Lang, P. J. (2010). Detecting novelty and significance. *Journal of Cognitive Neuroscience*, 22, 404–411

Ferrari V., Bradley M.M., Codispoti M., Lang P.J. (2011). Repetitive exposures: Brain and reflex measures of emotion and attention. *Psychophysiology*, 48,515-522.

Ferrari, V., Bradley, M.M., Codispoti, M., Lang, P.J. (2015). Massed and distributed repetition of natural scenes: Brain potentials and oscillatory activity. *Psychophysiology*, 52 (7), pp. 865-872.

Ferrari V, Bruno N, Chattat R, Codispoti M. (2017). Evaluative ratings and attention across the life span: emotional arousal and gender. *Cogn Emot*, 31(3), 552-563.

Ferrari, V., Codispoti, M., Cardinale, R., & Bradley, M. M. (2008). Directed and motivated attention during processing of natural scenes. *Journal of Cognitive Neuroscience*, 20, 1753–1761.

Folyi T, Wentura D. (2015). Fast and unintentional evaluation of emotional sounds: evidence from brief segment ratings and the affective Simon task. *Cogn Emot*, 31(2), 312-324.

Folyi T, Liesefeld HR, Wentura D. Attentional enhancement for positive and negative tones at an early stage of auditory processing. *Biol Psychol*, 114, 23-32.

Fox, E., Lester, V., Russo, R., Bowles, R., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion*, 14, 61–92.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion*, 16, 355–379.

Foxe, J.J., Snyder, A.C., 2011. The role of alpha-band brain oscillations as a sensory suppression mechanism during selective attention. *Frontiers in Psychology* 2. <http://>

Frijda, N.(1986). *The emotions*. New York: Cambridge University Press.

Frijda, N.(1988). The laws of emotion. *Am Psychol*, 43(5),349-58.

Gitelman, D.R.(2002).ILAB: a program for post-experimental eye movement analysis. *Behavior Research Methods, Instruments, and Computers*, 34, 605–612

Goubert, L., Crombez, G., Hermans, D., & Vanderstraeten, G. (2003). Implicit attitude towards pictures of back-stressing activities in pain-free subjects and patients with low back pain: An affective priming study. *European Journal of Pain*, 7, 33– 42.

Grabenhorst, F., & Rolls, E. T. (2011). Value, pleasure and choice in the ventral prefrontal cortex. *Trends in Cognitive Sciences*, *15*(2), 56–67. <https://doi.org/10.1016/j.tics.2010.12.004>

Greenhouse SW, Geisser S (1959) On methods in the analysis of profile data. *Psychometrika* 24:95-112.

Hahn, S., & Gronlund, S. D. (2007). Top-down guidance in visual search for facial expressions. *Psychonomic Bulletin & Review*, *14*(1), 159–165.

Hajcak, G., & Olvet, D. M. (2008). The persistence of attention to emotion: Brain potentials during and after picture presentation. *Emotion*, *8*(2), 250–255.

Hartikainen, K. M., Ogawa, K. H., & Knight, R. T. (2000). Transient interference of right hemispheric function due to automatic emotional processing. *Neuropsychologia*, *38*, 1576–1580.

Hayes, D.J., Northoff, G., 2011. Identifying a network of brain regions involved in aversion-related processing: a cross-species translational investigation. *Front. Integr. Neurosci.* 5, 49.

Herring, D. R., Taylor, J. H., White, K. R., & Crites, S. L. (2011). Electrophysiological responses to evaluative priming: The LPP is sensitive to incongruity. *Emotion*, *11*, 794–806.

Hilgard, J., Weinberg, A., Hajcak Proudfit, G., & Bartholow, B. D. (2014). The negativity bias in affective picture processing depends on top-down and bottom-up motivational significance. *Emotion*, *14*(5), 940–949.

Humphrey, K., Underwood, G., & Lambert, T. (2012). Saliency of the lambs: A test of the saliency map hypothesis with pictures of emotive objects. *Journal of Vision*, *12*(1), 1–15.

Insel, T. R., & Cuthbert, B. N. (2009). Endophenotypes: Bridging genomic complexity and disorder heterogeneity. *Biological Psychiatry*, *66*, 988–989.

Ito, T. A., Cacioppo, J. T., & Lang, P. J. (1998). Eliciting affect using the international affective picture system: Trajectories through evaluative space. *Personality and Social Psychology Bulletin*, 24, 855-879.

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality & Social Psychology*, 75, 887–900.

James, W. (1884). What is an Emotion? *Mind*, 9(34), 188–205.

Jensen, O., Mazaheri, A., 2010. Shaping functional architecture by oscillatory alpha activity: gating by inhibition. *Frontiers in Human Neuroscience* 4.

Johnson, R. Jr, & Donchin, E., (1985). Second Thoughts: Multiple P300s elicited by a single stimulus. *Psychophysiology*, 22, 182-194.

Johnson, R. Jr (1979). Stimuli with biological significance. In H. Begleiter (Ed.). *Evoked brain potentials and behavior* (pp. 1-12). New York: Plenum Press.

Johnston, V. S., Miller, D. R., & Burleson, M. H. (1986). Multiple P3s to emotional stimuli and their theoretical significance. *Psychophysiology*, 23, 684-694.

Junghofer, M., Elbert, T., Tucker, D. M., & Rockstroh, B. (2000). Statistical control of artifacts in dense array EEG/MEG studies. *Psychophysiology*, 37, 523–532.

Kerns, J. G. (2005). Positive schizotypy and emotion processing. *Journal of Abnormal Psychology*, 114, 392–401.

Kimble, G. A., & Ost, J. W. (1961). A conditioned inhibitory process in eyelid conditioning. *Journal of Experimental Psychology*, 61, 150–156.

Kissler, J., & Keil, A. (2008). Look—Don't look! How emotional pictures affect pro- and antisaccades. *Experimental Brain Research*, 188, 215–222.

Klauer, K. C. (1998). Affective priming. In W. Stroebe (Ed.), *European review of social psychology* (Vol. 8, pp. 67–103). Hoboken, NJ: Wiley

Klauer, K. C., & Musch, J. (2001). Does sunshine prime loyal? Affective priming in the naming task. *Quarterly Journal of Experimental Psychology Human Experimental Psychology*, 54A, 727–751.

Klimesch, W., 1999. EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain Research Reviews* 29 (2–3), 169–195.

Klimesch, W., 2012. Alpha-band oscillations, attention, and controlled access to stored information. *Trends in Cognitive Sciences* 16 (12), 606–617. <http://dx.doi.org/>

Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience Letters*, 244, 73–76.

Klimesch, W., Sauseng, P., Hanslmayr, S., 2007. EEG alpha oscillations: the inhibition-timing hypothesis. *Brain Research Reviews* 53 (1), 63–88

Konorski, J. (1967). *Integrative activity of the brain: An interdisciplinary approach*. University of Chicago Press, Chicago, IL.

Kozak, M. J., & Cuthbert, B. N. (2016). The NIMH Research Domain Criteria Initiative: Background, issues, and pragmatics. *Psychophysiology*, 53, 286–297.

Lang, P.J. (1979). A bio-informational theory of emotional imagery. *Psychophysiology*, 16, 495–512.

Lang, P. J. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In 1. B. Sidowski, J. H. Johnson, & T. A. Williams (Eds.), *Technology in mental health care delivery* (pp. 119–137). Norwood, NJ: Ablex.

Lang, P.J. (1985): The cognitive psychophysiology of emotion: Fear and anxiety. In: Tuma AH, Maser JD, editors. *Anxiety and the Anxiety Disorders*. Hillsdale, NJ: Erlbaum, pp 131–170.

Lang, P.J. (1994). The varieties of emotional experience: a meditation on James-Lange theory. *Psychol. Rev.* 101, 211–221.

Lang, P.J. (2010). Emotion and motivation: Toward consensus definitions and a common research purpose. *Emotion Review*, 2(3), 229-233

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention and the startle reflex *Psychological Review*, 97, 377–395

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Act, activation, and action. In P. Lang, R. Simons, & M. Balaban (Eds.), *Attention and orienting* (p. 97-135). Mahwah, NJ: Erlbaum

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8 Gainesville, FL: University of Florida.

Lang, P. J., & Davis, M. (2006). Emotion, motivation, and the brain: Reflex foundations in animal and human research. *Progress in Brain Research*, 156, 3–29.

Lang PJ, McTeague LM. (2011). Discrete and recurrent traumatization in PTSD: fear vs. anxious misery. *J Clin Psychol Med Settings*, 18(2), 207-9.

Lang PJ, McTeague LM, Bradley MM. (2014). Pathological anxiety and function/dysfunction in the brain's fear/defense circuitry. *Restor Neurol Neurosci*, 32(1), 63-77.

Lang PJ, McTeague LM, Bradley MM. (2016). RDoC, DSM, and the reflex physiology of fear: A biodimensional analysis of the anxiety disorders spectrum. *Psychophysiology*. 2016, 53(3):336-47

Lang, P. J., McTeague, L. M., & Bradley, M. M. (2014). Pathological anxiety and function/dysfunction in the brain's fear/defense circuitry. *Restorative Neurology and Neuroscience*, 32, 63–77. doi:

LeDoux, J. E. (1996). *The Emotional Brain*, Simon and Schuster, New York

LeDoux, J. (2012). Rethinking the Emotional Brain. *Neuron*, 73(4), 653–676.

Lykken, D. T., Macindoe, I., & Tellegen, A. (1972). Preception: Autonomic response to shock as a function of predictability in time and locus. *Psychophysiology*, 9, 318–333

Lindsley, D.B. (1951). Emotions. In *Handbook of Experimental Psychology*, S.S. Stevens, ed. (New York: Wiley), pp. 473–516.

McBride, W.J., Murphy, J.M., Ikemoto, S., 1999. Localization of brain reinforcement mechanisms: intracranial self-administration and intracranial place-conditioning studies. *Behav. Brain Res.* 101, 129–152

McSorley E, van Reekum CM (2013). The time course of implicit affective picture processing: An eye movement study. *Emotion*, 13, 769–773.

McTeague LM, Lang PJ, Laplante MC, Cuthbert BN, Strauss CC, Bradley MM. (2009). Fearful imagery in social phobia: generalization, comorbidity, and physiological reactivity. *Biol Psychiatry*, 65(5), 374-82.

McTeague LM, Lang PJ, Laplante MC, Cuthbert BN, Shumen JR, Bradley MM. (2010). Aversive imagery in posttraumatic stress disorder: trauma recurrence, comorbidity, and physiological reactivity. *Biol Psychiatry*, 67(4), 346-56.

Mehrabian, A., & Russell, J.A. (1974). The basic emotional impact of environments. *Perceptual and Motor Skills*, 38, 283-301.

Milanak, M. E., & Berenbaum, H. (2009). The relationship between PTSD symptom factors and emotion. *Journal of Traumatic Stress*, 22, 139–145.

Miller, N.(1944). Experimental studies of conict. In J. Hunt (Ed.), *Personality and the behavioral disorders* (Vol. 1, p. 431-465). New York: Ronald Press.

Miller, N. (1959). Liberalization of basic S-R concepts. In S. Koch (Ed.), *Psychology: A study of a science* (Vol. 2, p. 196-292). New York: McGraw-Hill.

Mogg, K., & Bradley, B. P. (1999). Orienting of attention to threatening facial expression presented under conditions of restricted awareness. *Cognition and Emotion*, 13, 713–740

Morris, J. S., Friston, K. J., Buchel, C., Frith, C. D., Young, A. W., Calder, A. J., & Dolan, R. J. (1998). A neuromodulatory role for the human amygdala in processing emotional facial expressions. *Brain*, 121, 47–57.

Moruzzi, G., and Magoun, H.W. (1949). Brain stem reticular formation and activation of the EEG. *Electroencephalogr. Clin. Neurophysiol.* 1, 455–473.

Niu, Y., Todd, R. M., & Anderson, A. K. (2012). Affective salience can reverse the effects of stimulus-driven salience on eye movements in complex scenes. *Frontiers in Psychology*, 3, 336.

Nummenmaa, L., Hyona, J., & Calvo, M. G. (2006). Eye movement assessment of selective attentional capture by emotional pictures. *Emotion*, 6, 257–268.

Nummenmaa, L., Hyönä, J., & Calvo, M. G. (2009). Emotional scene content drives the saccade generation system reflexively. *Journal of Experimental Psychology: Human Perception and Performance*, 35, 305–323.

O'Doherty, J.P., 2004. Reward representations and reward-related learning in the human brain: insights from neuroimaging. *Curr. Opin. Neurobiol.* 14, 769–776.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, 130(3), 466–478.

Ohman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology*, 80, 381–396.

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review*, *108*(3), 483–522. doi:10.1037/0033-295X.108.3.483.

Öhman, A., Soares, S. C., Juth, P., Lindström, B., & Esteves, F. (2012). Evolutionary derived modulations of attention to two common fear stimuli: Serpents and hostile humans. *Journal of Cognitive Psychology*, *24*(1), 17–32.

Okon-Singer, H., Tzelgov, J., & Henik, A. (2007). Distinguishing between automaticity and attention in the processing of emotionally significant stimuli. *Emotion*, *7*, 147–157

Ortony, A. et al. (1983) A puzzle about affect and recognition memory. *J. Exp Psychol Learn Mem Cogn.* *9*, 725–729

Osgood, C. E., Suci, G., & Tannenbaum, P.(1957). *The measurement of meaning*. Urbana, IL: University of Illinois.

Padmala, S., & Pessoa, L. (2014).Motivation versus aversive processing during perception. *Emotion*, *14*, 450–454.

Palomba, D., Angrilli, A., Mini, A. (1997). Visual evoked potentials, heart rate responses and memory to emotional pictorial stimuli. *Int J Psychophys*, *27*, 55-67.

Perdue, C. W., Dovidio, J. F., Gurtman, M. B., & Tyler, R. B. (1990). Us and them: Social categorization and the process of intergroup bias. *Journal of Personality and Social Psychology*, *59*, 475– 486.

Perdue, C. W., & Gurtman, M. B. (1990). Evidence for the automaticity of ageism. *Journal of Experimental Social Psychology*, *26*, 199–216.

Pereira, M. G., Volchan, E., De Souza, G. G., Oliveira, L., Campagnoli, R. R., Pinheiro, W. M., et al. (2006). Sustained and transient modulation of performance induced by emotional picture viewing. *Emotion*, *6*, 622– 634

Peyk, P., De Cesarei, A., & Junghofer, M. (2011). Electromagnetic encephalography software: Overview and integration with other EEG/MEG toolboxes. *Computational Intelligence and Neuroscience*, Article ID 861705.

Pessoa, L., McKenna, M., Gutierrez, E., & Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention. *Proceedings of the National Academy of Sciences*, 99(17), 11458–11463.

Phelps, E. A., Ling, S., & Carrasco, M. (2006). Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science*, 17, 292–299

Posner, M. I., Inhoff, A., Friedrich, F. J., Cohen, A. 1987. Isolating attentional systems: A cognitive-anatomical analysis. *Psychobiology*. 15, 107-21.

Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological Correlates of Rapid Spatial Orienting Towards Fearful Faces. *Cerebral Cortex*, 14(6), 619–633.

Pratto, L., & John, O. P. (1991). Automatic vigilance: The attention-grabbing power of negative social information. *Journal of Personality and Social Psychology*, 81, 380–391.

Pfurtscheller, G., 2003. Induced oscillations in the alpha band: functional meaning. *Epilepsia* 44, 2–8

Pfurtscheller, G., Stancák, A., Neuper, C., 1996. Event-related synchronization (ERS) in the alpha band — an electrophysiological correlate of cortical idling: a review. *International Journal of Psychophysiology* 24 (1–2), 39–46.

Radilova, J. (1982). The late positive component of visual evoked response sensitive to emotional factors. *Actas Nervosa Superior, Suppl 3(2)*, 334–337.

Rizzolatti G, Riggio L, Dascola I, Umiltá C. (1987). Reorienting attention across the horizontal and vertical meridians: evidence in favor of a premotor theory of attention. *Neuropsychologia*, 25(1A), 31-40.

Rizzolatti G, Riggio L, Sheliga, B.M. (1994). Space and selective attention. In C. Umiltá & M. Moschovich (Eds.). *Attention and Performance XV*, (pp. 231-265). Cambridge, MA: MIT Press.

Roefs, A., Stapert, D., Isabella, L., Wolters, G., Wojciechowski, F., & Jansen, A. (2005). Early associations with food in anorexia nervosa patients and obese people assessed in the affective priming paradigm. *Eating Behaviors*, 6, 151–163.

Rolls, E. T. (1999). *The brain and emotion*. Oxford, UK: Oxford University Press.

Rolls, E. T. (2005). *Emotion explained*. Oxford, UK: Oxford University Press.

Rolls, E. T. (2013). What are emotional states, and why do we have them? *Emotion Review*, 5(3), 241–247.

Rolls, E. T., & Grabenhorst, F. (2008). The orbitofrontal cortex and beyond: From affect to decision-making. *Progress in Neurobiology*, 86(3), 216–244.

Rozin, P., Royzman, E.B (2001). Negativity Bias, Negativity Dominance, and Contagion. *Person Soc Psych Rev*, 5(4), 296-320.

Rousselet, G.A., Fabre-Thorpe, M., Thorpe, S.J. (2002). Parallel processing in high-level categorization of natural images. *Nat Neurosci*, 5(7), 629-30.

Rousselet G, et al. How long to get to the “gist” of real-world natural scenes? *Vis. Cogn.* 2005;12:852–877.

Ruchkin, D.S., & Sutton, S. (1979). Equivocation and P300 amplitude. In D. Otto (Ed.). *Multidisciplinary perspectives in event related brain potential research* (pp. 175-177). Washington, DC: U.S. Government Printing Office.

Rushworth, M. F. S., Noonan, M. P., Boorman, E. D., Walton, M. E., & Behrens, T. E. (2011). Frontal Cortex and Reward-Guided Learning and Decision-Making. *Neuron*, 70(6), 1054–1069.

Russell, J. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*.

Russell, J.A. (2003). Core affect and the psychological construction of emotion. *Psychol. Rev.* 110, 145–172.

Russell, J. A., & Barrett, L. F. (1999). Core Affect, Prototypical Emotional Episodes, and Other Things Called Emotion: Dissecting teh Elephant. *Journal of Per*, 76(5), 805–819.

Sabatinelli D, Bradley MM, Fitzsimmons JR, Lang PJ.(2005). Parallel amygdala and inferotemporal activation reflect emotional intensity and fear relevance. *Neuroimage*, 24(4), 1265-70.

Sabatinelli D, Frank DW, Wanger TJ, Dhamala M, Adhikari BM, Li X. (2015). The timing and directional connectivity of human frontoparietal and ventral visual attention networks in emotional scene perception. *Neuroscience*, 277, 229-38

Sauseng, P., & Klimesch, W. (2008). What does phase information of oscillatory brain activity tell us about cognitive processes? *Neuroscience & Biobehavioral Reviews*, 32, 1001–1013

Schachter, S. (1975). Cognition and centralist-peripheralist controversies motivation and emotion. In *Handbook of Psychobiology*, M.S. Gazzaniga and C.B. Blakemore, eds. (New York: Academic Press), pp. 529–564.

Schachter, S., & Singer, J. E. (1977). Cognitive, Social, and Physiological Determinants of Emotional State. *Psychological Review*, 69(5).

Scherer, L. D., & Lambert, A. J. (2012). Implicit race bias revisited: On the utility of task context in assessing implicit attitude strength. *Journal of Experimental Social Psychology*, 48, 366–370.

Schimmack, U. (2005). Attentional interference effects of emotional pictures: Threat, negativity, or arousal? *Emotion*, 5, 55– 66

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-prime user's guide*. Pittsburgh, PA: Psychology Software Tools Inc.

Schneirla, T. (1959). An evolutionary and developmental theory of biphasic processes underlying approach and withdrawal. In M. Jones (Ed.), *Nebraska symposium on motivation* (p. 27-58). Lincoln, NE: University of Nebraska Press.

Schober, J., Weil, Z., and Pfaff, D. (2011). How generalized CNS arousal strengthens sexual arousal (and vice versa). *Horm. Behav.* 59, 689–695.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Hillman, C. H., Hamm, A. O., & Lang P. J. (2004). Brain processes in emotional perception: Motivated attention. *Cognition & Emotion*, 18 (5), 593-611.

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: Event-related brain potential studies. *Progress in Brain Research*, 156, 123-143.

Sege, C. T., Bradley, M. M., & Lang, P. J. (2014). Startle modulation during emotional anticipation and perception. *Psychophysiology*, 51, 977–981.

Sege, C. T., Bradley, M. M., & Lang, P. J. (2015). Prediction and perception: Defensive startle modulation. *Psychophysiology*, 52 (2015), 1664–1668.

Smith, N. K., Cacioppo, J. T., Larsen, J. T., & Chartrand, T. L. (2003). May I have your attention, please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia*, 41(2), 171–183.

Spruyt, A., De Houwer, J., Hermans, D., & Eelen, P. (2007). Affective priming of nonaffective semantic categorization responses. *Experimental Psychology*, 54, 44–53.

Spruyt, A., De Houwer, J., & Hermans, D. (2009). Modulation of automatic semantic priming by feature-specific attention allocation. *Journal of Memory and Language*, 61, 37–54.

Spruyt, A., Gast, A., & Moors, A. (2011). The sequential priming paradigm: A primer. In K. C. Klauer, A. Voss, & C. Stahl (Eds.), *Cognitive methods in social psychology* (pp. 48–77). New York, NY: Guilford Press.

Spruyt, A., De Houwer, J., Everaert, T., & Hermans, D. (2012). Unconscious semantic activation depends on feature-specific attention allocation. *Cognition*, 122, 91–95.

Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. *Psychological Bulletin*, 87, 245-251.

Suslow, T., Arolt, V., & Junghanns, K. (1998). Alexithymia and automatic activation of emotional-evaluative information. *Psychotherapie, Psychosomatik, Medizinische Psychologie*, 48, 168-175.

Suslow, T., Dannlowski, U., Arolt, V., & Ohrmann, P. (2010). Adult attachment avoidance and automatic affective response to sad facial expressions. *Australian Journal of Psychology*, 62, 181–187.

Suslow, T., Roestel, C., Droste, T., & Arolt, V. (2003). Automatic processing of verbal emotion stimuli in schizophrenia. *Psychiatry Research*, 120, 131–144.

Teghtsoonian, R., & Frost, R. O. (1982). The effect of viewing distance on fear of snakes. *Journal of Behavior Therapy and Experimental Psychiatry*, 13, 181–190.

Tallon-Baudry, C., Bertrand, O., Delpuech, C., & Pernier, J. (1997). Oscillatory gamma-band (30–70 Hz) activity induced by a visual search task in humans. *Journal of Neuroscience*, 17, 722–734.

Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin*, 110, 67–85.

Tellegen, A. (1985). Structures of Mood and Personality and Their Relevance to Assessing Anxiety, with an Emphasis on Self-Report. In A. H. Tuma, & J. D. Master (Eds.), *Anxiety and the Anxiety Disorders* (pp. 681-706). Hillsdale, NJ: Erlbaum.

Tinbergen, N. (1951). *The Study of Instinct* (New York: Oxford University Press).

Uusberg, A., Uibo, H., Kreegipuu, K., Allika, J. (2013). EEG alpha and cortical inhibition in affective attention. *Int J Psychophys*, 89(1), 26-36.

Vandenbosch, K., & De Houwer, J. (2011). Failures to induce implicit evaluations by means of approach–avoid training. *Cognition & Emotion*, 25, 1311–1330.

van Oyen Witvliet, C., Vrana, S.R. (1996). The emotional impact of instrumental music on affect ratings, facial EMG, autonomic measures, and startle reflex. [Abstract]. *Psychophysiology*, 33, S91

Veldhuizen, M. G., Oosterhoff, A. A., & Kroeze, J. H. A. (2010). Flavors prime processing of affectively congruent food words and non-food words. *Appetite*, 54, 71–76.

Venables PH, Christie MJ (1980) Electrodermal activity. In: Martin I, Venables PH, eds. *Techniques in Psychophysiology*. New York: John Wiley. pp 2–67.

Verbruggen, F., & De Houwer, J. (2007). Do emotional stimuli interfere with response inhibition? Evidence from the stop signal paradigm. *Cognition and Emotion*, 21, 391– 403.

Vermeulen, N., Luminet, O., & Corneille, O. (2006). Alexithymia and the automatic processing of affective information: Evidence from the affective priming paradigm. *Cognition & Emotion*, 20, 64–91.

Vogt J., De Houwer J., Koster E. H. W., Van Damme S., Crombez G. (2008). Allocation of spatial attention to emotional stimuli depends upon arousal and not valence. *Emotion*, 8, 880–885

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of Attention and Emotion on Face Processing in the Human Brain. *Neuron*, 30(3), 829– 841.

Vuilleumier, P., & Driver, J. (2007). Modulation of visual processing by attention and emotion: Windows on causal interactions between human brain regions. *Philosophical Transactions of the Royal Society of London Biological Sciences*, 362, 837– 855.

Weisbuch, M., & Ambady, N. (2008). Affective divergence: Automatic responses to others' emotions depend on group membership. *Journal of Personality and Social Psychology*, 95, 1063–1079

Whalen, P.J., Rauch, S.L., Etcoff, N.L., McInerney, S.C., Lee, M.B., Jenike, M.A., 1998. Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *J. Neurosci.* 18, 411 – 418.

Weinberg, A., & Hajcak, G. (2010). Beyond good and evil: The time- course of neural activity elicited by specific picture content. *Emotion*, 10, 767–782.

Wentura, D. (1999). Activation and inhibition of affective information: For negative priming in the evaluation task. *Cognition & Emotion*, 13, 65–91.

Wentura, D., & Degner, J. (2010). A practical guide to sequential priming and related tasks. In B. Gawronski & B. K. Payne (Eds.), *Handbook of implicit social cognition* (pp. 95–116). New York, NY: Guilford Press.

Wentura, D., & Rothermund, K. (2003). The “meddling-in” of affective information: A general model of automatic evaluation effects. In J. Musch & K. C. Klauer (Eds.), *The psychology of evaluation: Affective processes in cognition and emotion* (pp. 51–86). Mahwah, NJ: Erlbaum.

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods, Instruments, & Computers*, 42, 671–684

Wittenbrink, B. (2007). Measuring attitudes through priming. In B. Wittenbrink & N. Schwarz (Eds.), *Implicit measures of attitudes* (pp. 17– 58). New York, NY: Guilford Press.

Wundt, W. (1896). *Grundriss der psychologie* (6th ed.). Leipzig: Engelman.