The effects of emotional distractors on the performance of cognitive tasks

Giuliano Gaeta, MSc

Thesis submitted to the University of Nottingham for the degree of Doctor of Philosophy

May 2018

Abstract

Emotional stimuli can influence the performance of a cognitive task when presented in conjunction with it, although irrelevant to its completion. However, several criticalities and relevant gaps in the current literature on emotional distraction can be detected, and the present work aims to contribute to a better definition and understanding of the electrophysiological and, above all, behavioural correlates of the interaction between the two domains of cognition and emotion.

Following a brief overview of this manuscript, chapters 2-3 provide background information on emotions, their properties and their interaction with cognitive processes. Chapters 4-8 report five experiments conducted to study this interaction, all employing behavioural and self-reported measures, and the first comprising electroencephalographic recordings. Further, for the first time, we analysed how individual approach/avoidance dominance can be associated with the effects of emotional distractors on task performance. After studying the effects of the valence of the distractors and the effects of task difficulty, we analysed how different types of distractors (words and pictures) affected the completion of emotionally salient and neutral tasks. A general discussion commenting on the results obtained in all the studies closes this work.

The framework delineated here is absent in the current literature. The unicity and relevance of the work proposed lies particularly in the methodological approach toward the study of emotional distraction, which can in principle help to unveil the neural and behavioural mechanisms of physiological interaction between emotion and cognition dimensions.

"Tanto vale provarci comunque"

Federico Dragogna

"Cosa ti aspetti da me? Non è più la stessa cosa, credimi.
Io sono piccolo così e tu sei troppo grande per crederci."

To Piero and Katia, with all the love and gratitude I am capable of.

Table of Contents

1. Overview..... 13

2. The emotional stimuli: properties and processing. 17

2.1. Brief historical *excursus* on the evolution of the concept of emotion through philosophy. 17

2.2. What is an emotion? 20

2.2.1. The Differential Emotions Theory (DET). 21

2.2.2. Emotion generation and regulation..... 23

2.2.3. Limitations in the definitions of 'emotion'. 24

2.3. The theoretical conceptualization of emotions: valence, arousal and the main models of the emotional sphere. 25

2.3.1. A two-dimensional model of emotions: Russel's circumplex of emotions..... 26

2.3.2. The inclusion of emotional dominance: the PAD model. .. 27

2.3.3. A biologically grounded model: the cube of emotions. 28

2.4. Emotions at brain level: the cerebral structures involved in the emotional processes. 30

2.4.1. The first description of emotion-related circuitry: the limbic system and the Papez circuit. 30

2.4.2. Limitations of the Papez circuit: the extension of the limbic system. 32

2.4.3. The contribution of the cortical structures to emotional processing. 36

2.4.4. Cortical and subcortical structures simultaneously interact during the processing of emotions. 38

2.4.5. Two different functions within the same system: emotion and memory. 40

2.5. The frontal cortex in the processing of emotions: frontal asymmetries and theories explaining the neural patterns of activation. 42

2.5.1. A first theory for the frontal asymmetries: the right hemisphere hypothesis. 43

2.5.2. A stimulus-driven lateralization: the valence hypothesis. 44

2.5.3. The support from neuroimaging studies: involvement of the theta and alpha rhythms. 45

2.5.4. The motivational aims and the role of the individual: the behavioural systems theory. 46

2.5.5. A comparison between the valence hypothesis and the RST: the case of anger. 49

3. The interaction between emotional and cognitive processes.. 51

3.1. Cognition influences emotion. 52

3.2. Emotion influences cognition. 54

3.2.1. The automatic Vs competitive theories over the influence of emotion on cognition..... 54

3.2.2. How emotions influence goal-directed behaviour..... 55

3.3. How emotion influences cognition: enhancing or detrimental effects? 57

3.3.1. The enhancing effects of emotion on cognition. 57

3.3.2. The impairing effects of emotion on cognition..... 58

3.4. The effects of valence in the emotional distraction..... 60

3.4.1. Positive and negative emotional distractors have similar effects on task performance. 60

3.4.2. Positive and negative emotional distractors have different effects on task performance. 61

3.4.3. A possible explanation for this discrepancy: methodological limitations of the studies present in the current literature. 62

3.5. The effects of task manipulations in the study of emotional distraction. 64

3.5.1. Individual differences and personality traits related to emotions. 64

3.5.2. The influence of the type of distractor chosen. 67

3.5.3. The influence of the type of task chosen and the cognitive load required. 68

3.6. The effects of emotional distractors on working memory. 70

3.7. Aim of the current research and overview of the experimental paradigms proposed. 71

4. The effects of positive and negative emotional pictures on task performance: an EEG study. 75

4.1. Abstract. 75

4.2. Introduction. 76

4.3. Materials and methods. 80

4.3.1. Participants. 80

4.3.2. Task and procedure. 80

4.3.3. Stimuli used. 82

4.3.4. EEG recordings and behavioural measures. 84

4.3.5. EEG coherence analysis. 86

4.3.6. Statistical analysis. 91

4.4. Results. 92

4.4.1. Behavioural systems dominance. 92

4.4.2. Behavioural measures for the RT task. 92

4.4.3. Behavioural measures for the memory task and the valence rating task. 93

4.4.4. Functional connectivity analysis: coherence scores. 93

4.4.5. Brain-behavioural correlations. 95

4.5. Discussion. 97

4.5.1. Task performance: effects of positive and negative distractors at the behavioural level. 98

4.5.2. Memory task performance: the relevance of emotionally salient distractors. 102

4.5.3. Functional connectivity analysis: a stronger involvement of the left hemisphere. 102

4.5.4. Brain-behavioural correlations: two independent frontal networks for valent distractors. 104

4.5.5. Lateralization in the emotional processing and influence on task performance. 105

4.5.6. Limitations of the current study and future directions. .. 106

5. Emotional distractors influence the performance of a task with different cognitive load levels. 108

5.1. Abstract. 108

5.2. Introduction. 109

5.3. Materials and methods. 114

5.3.1. Participants. 114

5.3.2. Task and procedure. 114

5.3.3. Preliminary analyses and results from pilot studies. 117

5.3.4. Stimuli used. 117

5.3.5. Statistical analysis. 119

5.3.6. Data pre-processing. 120

5.4. Results. 121
5.4.1. Behavioural dominance..... 121
5.4.2. RT task analysis: emotional condition. 121
5.4.3. RT task analysis: control condition. 122
5.4.4. Combined analysis on RTs and accuracy for the emotional and control conditions. 123
5.4.5. Memory task and rating task analyses. 124
5.4.6. Trait-performance correlations. 124
5.5. Discussion. 126
5.5.1. Task performance: effects of positive and negative distractors at the behavioural level. 127
5.5.2. The effects of task demands and emotional distraction on different levels of cognitive load. 130
5.5.3. Memory task performance: the absence of modulation by valence in the mnemonic recall. 131
5.5.4. Trait-performance correlations: the modulation effect of the activation system. 133
5.5.5. Limitations of the current study and future directions. .. 134
6. Emotional distracting words and pictures differently affect cognitive task performance. 136
6.1. Abstract. 136
6.2. Introduction. 137
6.3. Materials and methods. 140
6.3.1. Participants. 140
6.3.2. Task and procedure..... 140
6.3.3. Stimuli used. 143
6.3.4. Statistical analysis. 145

6.3.5. Data pre-processing. 146
6.4. Results. 147
6.4.1. Behavioural dominance..... 147
6.4.2. RT task analysis..... 148
6.4.3. Memory task analysis. 149
6.4.4. Trait-performance correlations. 151
6.5. Discussion. 151
6.5.1. A partial advantage for positive emotional stimuli. 152
6.5.2. Task accuracy: words and pictures behave differently. . 154
6.5.3. Memory recall performance: the type of stimulus affects the recognition rates. 155
6.5.4. Trait-performance correlations: the effects of trait impulsivity. 157
6.5.5. Limitations of the current study and future directions. .. 158
7. Perceptual complexity of emotional distractors affects the responses to emotional targets of opposite valence. 159
7.1. Abstract. 159
7.2. Introduction. 160
7.3. Materials and methods. 164
7.3.1. Participants. 164
7.3.2. Task and procedure..... 164
7.3.3. Stimuli used. 167
7.3.4. Statistical analysis. 169
7.3.5. Data pre-processing. 171
7.4. Results. 172
7.4.1. Behavioural dominance..... 172

7.4.2. RT task analysis..... 172
7.4.3. Memory task analysis. 176
7.4.4. Trait-performance correlations. 177
7.5. Discussion. 179
7.5.1. Task performance: a significant difference between positive and negative stimuli..... 179
7.5.2. The role of distractors' features: complexity of the pictures and familiarity of the words affect task performance. 181
7.5.3. Memory recall performance: a higher salience of emotional pictures. 182
7.5.4. Trait-performance correlations: a significant association only for emotional pictures. 183
7.5.5. Limitations of the current study and future directions. .. 184
8. Perceptual complexity of emotional distractors affects the responses to emotional targets of congruent valence. 185
8.1. Abstract. 185
8.2. Introduction. 186
8.3. Materials and methods. 189
8.3.1. Participants. 189
8.3.2. Task and procedure..... 189
8.3.3. Stimuli used. 192
8.3.4. Statistical analysis. 194
8.3.5. Data pre-processing. 196
8.4. Results. 197
8.4.1. Behavioural dominance..... 197
8.4.2. RT task analysis..... 197
8.4.3. Memory task analysis. 198

8.4.4. Trait-performance correlations. 199

8.5. Discussion. 200

8.5.1. Task performance: a clear difference between types of stimuli employed. 200

8.5.2. Stimuli properties: how perceptual complexity affects differently the valence judgement of congruent stimuli. 202

8.5.3. Mnemonic recall task: the interaction between the type and the valence of the stimuli. 203

8.5.4. Limitations of the current study and future directions. .. 204

9. General discussion. 206

9.1. The effects of valence: positive and negative distractors behave differently. 207

9.2. The effects of type of stimuli: emotional words and pictures do not hold the same distracting properties. 210

9.3. The memory of emotional distractors: how the valence and the type of the stimuli affect mnemonic recall. 213

9.4. How the specific properties of emotional distractors influence their effects on task performance. 216

9.5. The effects of the type of task: distraction does not have homogeneous effects on all cognitive tasks. 219

9.6. Personality traits: differences in the modulatory effects of BIS and BAS. 223

9.7. Limitations and potential applications of the current research. 227

9.8. Summary of the findings. 230

References. 233

Appendix 1 – Stimuli used 291

Appendix 2 – Pilot studies run before each experiment. 301

Acknowledgements. 312

1. Overview.

This thesis will illustrate the outcome of a body of research consisting of five experiments, aiming to define the effects of differently valent emotional distractors on the performance of a cognitive task.

Past investigation has highlighted how emotionally salient, although task-irrelevant stimuli presented in conjunction with a cognitive task have the power to influence the responses provided to the task itself. However, in the study of emotional distraction, several criticalities and relevant gaps in the current literature can be detected. The present work aims to contribute to a better definition and understanding of the electrophysiological and, above all, behavioural correlates in the interaction between the two domains of cognition and emotion.

The first study aimed at defining the role of valence in the effects that emotional distractors have on task completion. There is no consensus on this topic in the current literature: while a body of research supports the idea that positive and negative distractors have the same –detrimental- effects on the performance of a concurrent task, other studies highlighted significant differences in the influence of positive and negative stimuli. We designed an EEG-based experiment in which participants completed a numerical magnitude comparison task interspersed with emotional pictures from the IAPS database. Results highlighted a different influence of positive and negative distractors, the latter leading to a significantly worse performance in terms of higher RTs. Hence, negative distractors had significantly higher detrimental effects on task performance than the positive. Moreover, we identified two frontal cortical networks, one per hemisphere, possibly involved in the processing of the distracting stimuli. Therefore, even in the case of stimuli not explicitly attended, the left hemisphere appears

activated by positive stimuli, while the right one by negative stimuli.

The second study aimed to clarify whether this advantage from positive distraction is affected by the difficulty of the concurrent task. Past research did not agree on this: a line of studies proposed that higher cognitive load would prevent the full processing of emotional distractors. Consequently, there would not be differences in the effects of positive and negative distractors on task performance. Another group of studies claims that emotional stimuli would receive prioritised processing regardless of the task, therefore the differences between positive and negative distractors would still be present. We set up a behavioural experiment, in which the Sternberg delayed response task was used in conjunction with the same positive and negative IAPS pictures employed as distractors in the previous study. Our results suggested that the advantage for positive stimuli is unaffected by the level of attentional and cognitive resources required by the task.

The third study aimed to state whether the type of distractor chosen would influence the previously illustrated advantage in task performance following the presentation of positive distractors. Past literature suggested possible differences across types of stimuli, without however employing more than one type of distractor in a single experiment to directly compare the effects. Through a numerical magnitude comparison task interspersed with emotional pictures from the NAPS database and words from the Warriner database, we highlighted a different behaviour of distracting words and pictures. The former showed significant advantages in task performance for the positive, compared to the negative, stimuli. The latter, instead, did not show significant differences between positive and negative stimuli.

The fourth study aimed to determine the effects of the type of task and its relation to the different types of distractors: most studies in the literature used tasks without any emotional charge, while it is unclear how distractors behave in an emotionally salient task. Moreover, we aimed to determine whether the perceptual complexity of the distractors could influence their effects on task completion: this element has been rarely analysed in the field of emotional distraction. Using the same distractors of the previous study in conjunction with a valence judgement task, in which targets and distractors had incongruent valence levels, we outlined again an advantage brought in by positive distractors, particularly evident for pictorial, compared to written, stimuli. Moreover, low-complex stimuli appear to have stronger distracting power on task completion than the high-complex ones.

Eventually, the fifth study aimed to determine whether emotional congruence between targets and distractors would bring to a different effect compared to a situation of incongruence. The setup was identical to the previous study except for the congruent target-distractor match in terms of valence. Results highlighted again an advantage brought in by positive distractors, particularly when their complexity level is low.

Within all the studies, we analysed the recall rates of the emotional stimuli, which were implicitly memorised, meaning that they were attended by the participants but, at the same time, irrelevant with respect to the task. Results highlighted higher accuracy rate of recall and classification for pictorial, compared to written, stimuli.

Moreover, within all studies, we analysed how individual personality traits (behavioural dominance, trait impulsivity and trait anxiety) can be associated with the effects of emotional distractors on task performance. This parameter has never been considered in previous research on emotional distraction and, in general, often overlooked in the study of emotional perception.

The inverse correlation between personality traits and task performance appeared to be consistent for the positive distractors, while less pronounced for the negative ones.

The framework delineated here is absent in the current literature. The unicity and relevance of the work proposed lies not only in the methodological approach toward the study of emotional distraction, which can in principle help to unveil the neural and behavioural mechanisms of physiological interaction between emotion and cognition dimensions. In addition, the definition of a role for emotional distractors can potentially be exploited in the treatment of emotion- and attention-related psychopathologies (ADHD, PTSD, etc.).

2. The emotional stimuli: properties and processing.

"Human behaviour flows from three main sources: desire, emotion and knowledge" (Plato)

"One of the ultimate challenges for biology is to understand the brain's processing of unconscious and conscious perception, emotion, and empathy". (Eric Kandel)

2.1. Brief historical *excursus* on the evolution of the concept of emotion through philosophy.

The investigation of human emotions traces back to the beginning of philosophical thought, more than 20 centuries ago. The forefather of this stream of philosophy was Plato (428 B.C. – 348 B.C.), who first sketched in his *Republic* (ca. 390-360 B.C.) a difference between reason and emotion. He described them as two horses pulling the same chariot (the human being) in two opposite directions. In his view, emotion was considered as subordinate to rationality and driven by motivational means.

Aristotle (384 B.C. – 322 B.C.) provided the first broad description of the human emotional sphere: in his *Rhetoric* (ca. 330 B.C.), he established a clear definition of *pathe*, passions, as 'those things that cause people to change their minds in respect of their judgments and are accompanied by pleasure and pain'. Fourteen basic emotions represent *pathe*: these are differentiated not only in terms of positive-negative connotations but also in terms of the intensity of their effects. They are mainly considered as passive states of the soul, requiring an external stimulus to trigger the emotional state within the human being. This passiveness of emotions would not allow the individual to exercise any form of regulation on them. However, being emotions driven by

motivational purposes, the upsurge and cultivation of the individual emotional disposition suitable to their correct reception, in conjunction with further factors like age, gender and social status, could lead to an individual modulation of the emotion conveyed by a stimulus. In this fashion, the relationship between the object perceived and the emotion sprung within the individual assumes unique connotations within each human being. In his view, however, Aristotle considered the effects of emotional states as mostly detrimental: they would distract the person during his reasoning and would prevent the optimal performance of his tasks.

Roman philosophy, and in particular Stoicism (a current born in the first century B.C.), supported the Greek view that represented emotions negatively, as described mainly by the works of Cicero (106 B.C. – 43 B.C.) and Seneca (4 B.C. – 65 A.D.). The word used to label emotional experiences was *perturbatio,* often intended as a disadvantageous effect on physiological, rational behaviour. Stoic philosophy considered again emotions as fully passive states, without any imaginable voluntary modulation. The response that the human being provides is fully automatic and constant for any individual, being impossible to control.

Stoics also first theorised a model of emotional states that included four fundamental conditions: two of them are positive (*libido*, lust, and *laetitia*, delight) and two negatives (*metus*, fear, and *aegritudo,* distress). Moreover, the first of the two elements in both the positive and negative pairs (lust and fear) brings in stronger effects on the human being compared to the second.

While in the classic philosophy emotions were seen as pure conditions of the soul, the advent of the Galenist medical theories (second century A.D.) gave rise to the first links between the emotional sphere and the body. In particular, Galen (129-216) associated the three most relevant organs of the human body –

brain, heart and liver- with three abstract functions –reason, emotion and desire respectively-: each organ would produce secretions (*spirits*) in the form of blood and *pneuma* (air) that could influence the physiology of the human body.

Thomas Aquinas (1225-1274) gave a fundamental contribution, during the Middle Ages, to a better description of emotions, mediating the Christian and scientific knowledge on the topic and bringing it towards the modern era of thought. In his *Summa Theologiae* (1265-1274), he considered emotions as the result of the motion of a sensitive power embodied in the human being, which provoked physiological reactions like increases in temperature and heart rate. In his analysis, the experiencer of the emotions plays a fundamental role: without the perception from the senses, there cannot be an emotional reaction. Emotions, therefore, assume a concrete, real fashion: they are no longer just attributes of the soul. In Aquinas's view, emotions keep on being passive states, necessitating an external stimulus to trigger the emotional experience and reaction; however, for the first time, he theorizes the possibility of a control of this reaction through reason. This modulation is what allows the human being to experience both basic emotions, just like all animals, and ones that are more complex: in particular, he considered "good" all the moderate passions, while "noxious" the ones leading to more extreme reactions (typical of the animal reign). Particularly illuminating in Aquinas's theory of emotions is the description he gave of rage, considered a negative emotion but driven by motivational purposes.

During the Renaissance, in his *De anima et vita* (1538) Juan Luis Vives (1493-1540) referred, for the first time, to emotions as *affectus:* since then, the term became commonly used. Moreover, unlike the classical views, he theorizes a dual effect of emotions on

human behaviour, both detrimental and constructive according to the type of emotional and cognitive processes ongoing. His theory establishes a strong presence of the rational component in the modulation of the effects of an emotional stimulus, particularly in relation to the strength of the emotional response elicited.

2.2. What is an emotion?

More recently, in particular in the last decades, the study of human emotions gave rise to a plethora of theories and hypotheses aiming to describe these phenomena, most of which embody some of the elements already present in the philosophical speculation from the past centuries. The advancement was achieved essentially thanks to the advent of modern methodological techniques allowing the analysis of brain activity during the processing of emotional stimuli, along with a more organised and systematic approach to scientific research. This range of theories, however, in conjunction with the general breadth of the field of study, led to a lack of clarity and uniformity even in the most basic description of the emotions, like the answer to the central question: what are emotions? How can we define them? More than 35 years ago Kleinginna and Kleinginna (1981), at the dawn of the contemporary research on the topic, categorized in nine different groups a series of over a hundred definitions of the term "emotion" taken from different articles and textbooks, according to the theoretical issues challenged (taking into account, for example, internal mechanisms of emotions or their functional processes).

2.2.1. The Differential Emotions Theory (DET).

A decade after, Carroll Izard and colleagues provided a successful description of the concept of emotion establishing the Differential Emotions Theory (DET) (Ackerman, Abe & Izard, 1998). According to the DET, an emotion is the sum of three different components: "neurochemical processes, expressive behaviour and subjective experience or feeling state" (p. 86). Izard distinguished two constructs that build up the concept of emotion: the basic emotions, considered as 'natural kinds', and the 'emotional schema'. The two differ ontogenetically: while the former is a set of fundamental emotions developed in the first few months of the life of a human being, the latter is described as more conscious and causal process, defined as the interactions between the basic emotions and higher-order cognitive processes. Izard delineated a basic emotion as "a set of neural, bodily/ expressive, and feeling/motivational components generated rapidly, automatically, and non-consciously when ongoing affective–cognitive processes interact with the sensing or perception of an ecologically valid stimulus to activate evolutionarily adapted neurobiological and mental processes. The resulting basic emotion pre-empts consciousness and tends to drive a rather narrowly focused stereotypical response strategy to achieve an adaptive advantage" (Izard, 2007, pp. 261-262). Basic emotions are therefore elicited by simple, direct stimuli that do not require cognitive modulation, have unique physiological signatures that do not change over the lifespan and, by motivational means, can influence cognition and action as the organism provides a response to the emotional cue. The processes described not only are expressed in children as young as four months of age but are also universal, as confirmed by cross-cultural studies analysing electrophysiological and muscular responses to basic emotions (cf. Barrett, 2006). This invariance does not allow the inclusion of emotional schema as

natural kinds: in the case of cognitive modulation of emotions, in fact, the cultural factor can be decisive, bringing to differences across populations. Therefore, according to DET, an emotion is considered as the unitary entity that permits to build up the emotional sphere of the human being: a set of few (less than a dozen) emotions can generate the whole complex of emotional experiences of the individual (Izard, 2009). Moreover, what is evident from the DET is the evaluation of emotions as physical elements, rather than abstract concepts: they are not considered the cause of the behavioural responses from the body, but the response itself, a phase of the individual's neurobiological activity.

The proposed theory attempted to provide a definition of the concept of emotion. However, despite a part of the scientific community judging this definition valid, another part remained sceptical for various reasons. Turner and Ortony (1992), among others, argued that the criteria adopted for the inclusion of some emotions in the set of the basic elements are rather weak. For example, the specific activation of a group of facial muscles is only a minor behavioural response generated within an emotional state, undeniably present and unique, but undoubtedly limited and less salient than other neurobiological changes to describe a particular mental state in its entirety. Moreover, the whole array of physiological responses associated with an emotion is considered as not univocal: the authors argue that it is impossible to separate the changes due exclusively to the emotional states and those driven by concurrent factors (for example, of the cognitive kind). For these reasons, it appears impossible to establish a pre-defined set of basic emotions (and therefore a definition of emotion itself) based on the indications provided by the DET.

2.2.2. Emotion generation and regulation.

Moving from the DET, Gross, Sheppes, and Urry (2011) brought in another element in the definition of emotion: the distinction between emotion generation and its regulation. An emotion is generated when "a person-situation transaction compels attention, has a valenced meaning to an individual, and gives rise to a coordinated yet malleable multi-system response to the ongoing person-situation transaction" (p.766). In their description, the three prominent elements for the generation of an emotion are the relevance of the contingent situation/stimulus to the individual's goals (a motivational drive of the emotions), the behavioural and neurobiological changes in the individual and the sensitivity to the environmental cues. In this view, emotion generation embodies the fundamental elements of the basic emotions as defined in the DET, without however limiting the number of items in the list of the basic emotions. Emotion regulation, instead, is viewed as a partly cognitive process, matching the definition of emotional schema given by the DET. Some authors argue that emotions are self-regulatory processes, and that emotion regulation is nothing more than a new emotion (or one further step within an emotional schema) that replaces the previously ongoing one (Kappas, 2011). In this view, the distinction between emotion generation and regulation becomes superfluous and the whole process can be defined 'emotion' broadly.

Kauffman (2015) highlighted, instead, a difference, in the broad concept of emotion, between two biological features: "phenomenal feelings, divisible into two broad categories: positive (pleasurable) or negative (painful); and behaviour, their coupled 'action tendencies', also in binary categories: approach or avoidance. Together the feelings and their hardwired motor responses give rise to a pattern called hedonic behaviour" (p. 546). In this view, feelings are regarded as the basic emotions, a set of natural kinds;

behaviour instead forms what in the DET has been defined as emotion schema, that is, a more complex set of emotions strictly intertwined with the cognitive side of the emotional processing. Moreover, from a phylogenetical perspective, feelings are judged as the most ancestral response to perception, and emotion is viewed as "an entire sensory system; perhaps the first sense to have emerged upon the evolutionary stage, the grandfather of all senses such that its ancient hedonic logic remains encoded within them all" (p. 548). From this standpoint, emotion is not only linked with body response but represents the phylogenetic cornerstone of perception.

2.2.3. Limitations in the definitions of 'emotion'.

Several other theories during the last century have attempted to define of the concept of "emotion" and, along with it, to establish a series of normative criteria allowing the inclusion of different elements in a core set of basic emotions. However, even the number of what can be called "basic emotions" can range from only two to about 20 different elements (Ortony & Turner, 1990). This shows how hard it is to even theoretically define the nucleus of emotions. This drift has been left unchanged until nowadays. In fact, researchers still tend to disagree on the single definition of emotion, preferring to provide multiple ones, according to the specific aspect that each author tackles in his/her own research, stressing the accent on the different components (motivational, neural, functional, etc.) that characterize the individual point of view on emotions (Izard, 2010). While there appears to be a general agreement on some functions of the emotional states (emotions 'recruit response systems' and 'motivate cognition and action') and structures involved in the emotional experience ('dedicated neural systems' and 'response systems'), there is a

general lack of agreement on how the concept of emotion can be defined.

This brief overview exemplifies how hard –and perhaps futile- is the attempt to define the term "emotion". In fact, while no consensus is shown in the definition of the term 'emotion', academics agree on what it represents at a biological level, with regard to its components and characteristics. This is why many investigators have attempted to describe the properties of emotions, rather than giving a formal definition of the concept.

2.3. The theoretical conceptualization of emotions: valence, arousal and the main models of the emotional sphere.

The most successful operative description of emotions embroils the two dimensions of *valence* and *arousal* (Schlosberg, 1954). Valence accounts for the level of pleasantness, allowing a distinction between positive (joy, surprise…) and negative (fear, disgust…) emotions. Arousal describes the level of activation of an emotion, the degree of intensity that it generates within the individual experiencing it: this dimension accounts for differences between low-arousing (calm, sadness…) and high arousing (fear, elation…) emotions. The two dimensions are often flanked by the third dimension of *dominance*, that defines the level of control that the individual has over the emotional state, and it accounts for differences between dominance ("a feeling of control and influence over one's surroundings") and submissiveness ("feeling controlled or influenced by situations and others") (Mehrabian, 1996, p.263).

2.3.1. A two-dimensional model of emotions: Russel's circumplex of emotions.

In a ground-breaking paper on the topic, Russell (1978) pointed out the relationships between these three affective dimensions showing how, in a verbal valence judgement task on words naming different emotional states, the first two dimensions (valence and arousal) accounted for the vast majority of the variance in a principal components analysis (beyond 80%). In this study, participants were required to classify a series of words describing several emotional states according to different one-dimensional descriptors. Results showed how valence, in particular, could be considered the first dimension of affect, immediately followed by arousal: "pleasure and arousal are essential to the meaning of emotion terms", (p.1166). Following the main two, the description of emotions using multiple dimensions becomes more complex, without a clear strong third element: dominance appears to be a suitable candidate to define affective states, but its contribution remains limited and inferior in comparison to valence and arousal.

One year later, Russell (1979) illustrated the relationships between these two main affective dimensions: for the first time, he adopted the concept of a bipolar *affective space*, moving from the conceptualization of emotions as single, monopolar scales or, as other studies had previously suggested, a three- or even four-dimensional space to a bipolar one (cf. Thayer, 1967). He found that valence and arousal can be considered as orthogonal, giving rise to a Cartesian plane in which the x- and y-axes are represented by each dimension. Each emotion can, therefore, fit within this plane as a point in the two-dimensional space, with unique coordinates on the axes. This representation has lately been named the *circumplex of emotions* (Russell, 1980). In its original formulation, this model contained 28 basic emotional

states organised in the four quadrants of the affective plane (Fig. 1).

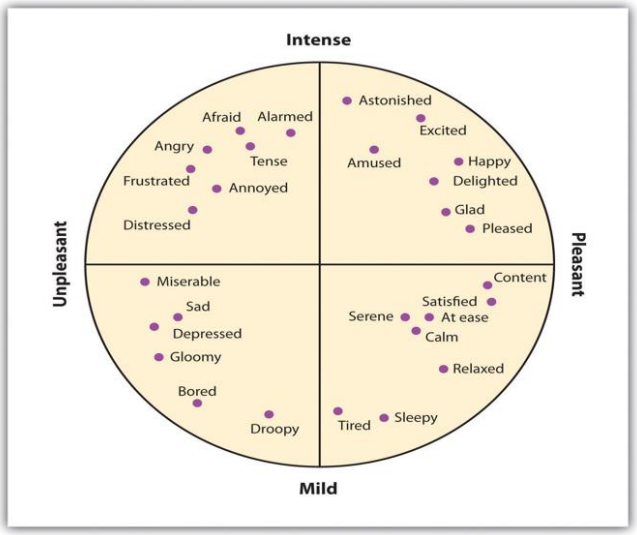


Fig. 1 – The circumplex model of affection (Russell, 1980).

The model proposed by Russell stands theoretically in contrast with the one proposed by Izard: in fact, within the circumplex of emotions, the number of combinations of valence and arousal are infinite, as the points of the Cartesian plane (Posner, Russell & Peterson, 2005). For this reason, the number of elements (emotions) available is infinite as well. Within the DET instead, the number of basic emotions is not only fixed but also extremely limited in size: emotions are seen like colours so that from the basic ones, the whole spectrum of shades arises.

2.3.2. The inclusion of emotional dominance: the PAD model.

This planar organisation of the human emotive sphere has been widely accepted and, even nowadays, is the reference model for the description of the emotional states. However, some authors did

not agree with the selection of only two of the three affective dimensions, preferring to include in their descriptive model the third one, dominance: this gave rise to the PAD (Pleasure-Arousal-Dominance) model of emotions (Mehrabian, 1996). The main argument for the inclusion of the third dimension in the model is the improvement not only in the qualitative description of emotional states but also in a sharper differentiation between the single emotions. However, despite the apparent contrast, the two theories should not be considered as antagonists, as they have been used to describe slightly different processes. In fact, the three-dimensional model has been traditionally exploited to illustrate the properties of stable, persistent emotional *traits* rather than transitory, short-timed and stimulus-driven emotional *states*, for which the bipolar model is probably the gold standard in terms of descriptive power. This is particularly true considering that dominance is the affective dimension with the highest cognitive component, able to express stronger effects on emotional schema rather than on basic emotions.

2.3.3. A biologically grounded model: the cube of emotions.

Along with the bi- and tri-dimensional models illustrated, other researchers tried to describe basic emotions tackling the issues from a tighter biological perspective. One of the most successful attempts was provided by Lövheim (2012), with his three-dimensional model defined as the "cube of emotions" (Fig. 2). In this model, Lövheim considered three monoamine neurotransmitters (noradrenaline, dopamine and serotonin) as the three axes of a Cartesian space, and linked eight basic emotions (the ones described by Tomkins & McCarter, 1964) with high or low levels of each neurotransmitter. These have been linked to a

particular aspect of emotions: "the serotonin axis seems to represent aspects such as self-confidence, inner strength and satisfaction. The dopamine axis has been found to be involved in reward, motivation and reinforcement, while noradrenaline has been coupled to the fight or flight response and to stress and anxiety, and appears to represent an axis of activation, vigilance and attention" (Lövheim, 2012, p. 342).

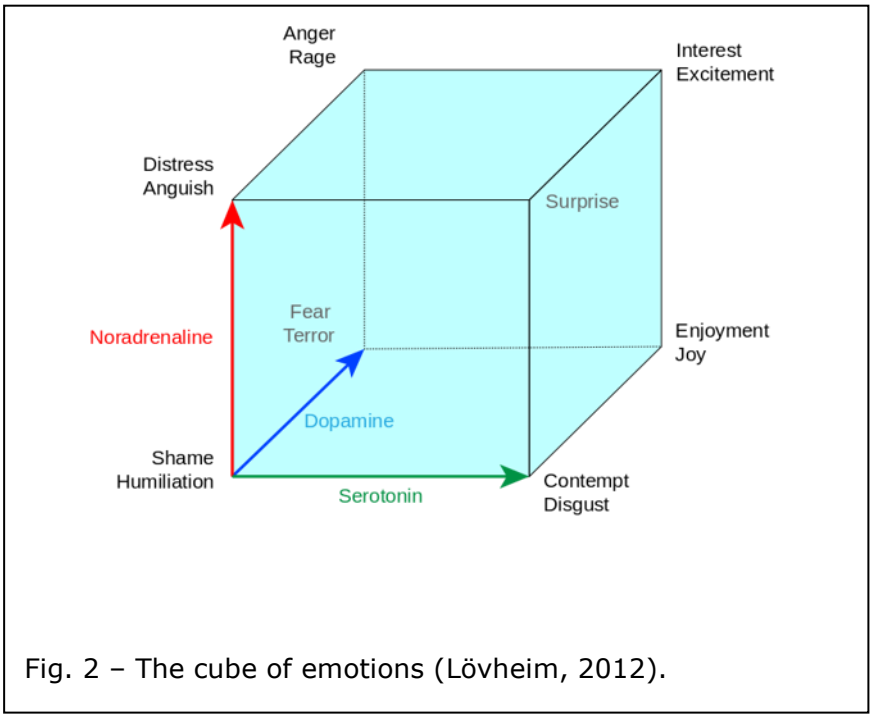


Fig. 2 – The cube of emotions (Lövheim, 2012).

The author, however, points out a substantial difference between this model and the PAD one: "the pleasantness dimension […] is not identical to either one of the serotonergic or dopaminergic axes. These earlier models thus seem somewhat rotated compared to the model presented" (p. 345).

This model has been successfully utilized in the field of artificial emotions research, a stream of investigation aiming to digitally reproduce the neural activity during the emotional experience and

apply it to artificial intelligence (see, for example, Kugurakova, Talanov, Manakhov, & Ivanov, 2015). The authors created a computation agent able to interact in real time with humans through a Brain-Computer Interface (BCI), whose behaviour and expression of emotions is modelled on the Lövheim's cube.

Neurotransmitters are however only a small –although extremely relevant- component of the biological grounds of emotions. In the last decades, in fact, psychologists and neuroscientists attempted to find and describe (both anatomically and physiologically) the cerebral structures responsible for the representation of emotional states. This analysis moves the emphasis from a more theoretical framework, for some aspects closer to philosophical speculation, to a more pragmatic one, where the ultimate aim is to define the neural signatures (and, more broadly, the behavioural responses and neurobiological changes) specific to emotional processes.

2.4. Emotions at brain level: the cerebral structures involved in the emotional processes.

2.4.1. The first description of emotion-related circuitry: the limbic system and the Papez circuit.

The task to link a specific emotion to the activity of a particular area of the brain is doubtlessly complex, probably utopic: however, several brain structures consistently contribute to the processing of emotional stimuli. One of the first and possibly most famous descriptions of the neural circuitry involved in the emotional experience was provided by Papez (1937), not surprisingly lately named "Papez circuit" (Fig. 3). In his description, the processing of emotional stimuli starts at the level of the hippocampal formation (subiculum) and involves the fornix, the mammillary bodies, the

mammillothalamic tract, the anterior thalamic nucleus, the cingulum, the entorhinal cortex and the hippocampal formation. This loop composes the core limbic system.

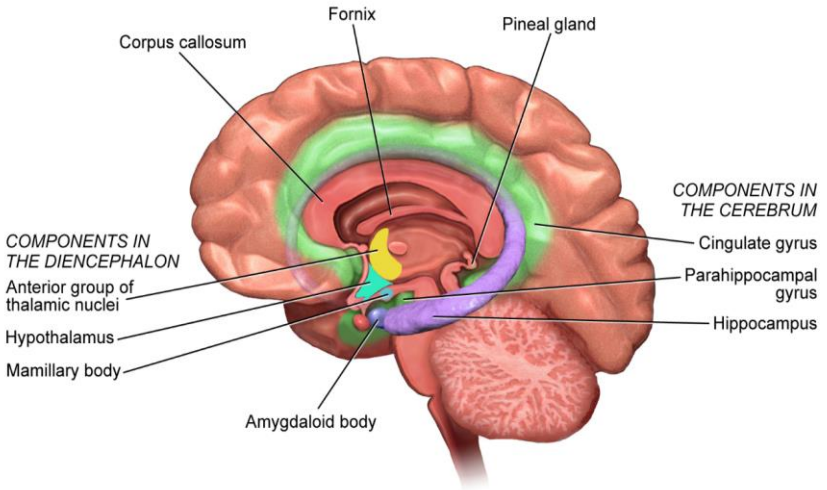


Fig. 3 – The Papez circuit in its original description (Papez, 1937).

In this historical paper, Papez started his analysis from lesion studies and anatomical dissections to establish the neural bases of emotions, grounding his work on the physical connections between the nodes of this circuit. These structures would all contribute to the processing of emotional stimuli and the subsequent reaction of the person perceiving them. However, he made a clear distinction between emotional expression (or "way of acting") and emotional experience (or "way of feeling", also commonly referred as affect). The latter is a subjective feature, the way an individual reacts to emotional stimuli. The former is an intersubjective condition that explains how emotions generally arise in the individuals. These two ways have not only functional but also anatomical differences. The element of conjunction between them is, according to Papez, the thalamus. It is viewed as a trading port, where the two ways of feeling and acting take different neural pathways (and can,

therefore, be differentiated). At this level, "the afferent pathways from the receptor organs split at the thalamic level into three routes, each conducting a stream of impulses of special importance. One conducts impulses through the dorsal thalamus and the internal capsule to the corpus striatum (stream of movement). The second conducts impulses from the thalamus through the internal capsule to the lateral cerebral cortex (stream of thought). The third conducts a set of concomitant impulses through the ventral thalamus to the hypothalamus, and by way of the mammillary body and the anterior thalamic nuclei to the gyrus cinguli, in the medial wall of the cerebral hemisphere (stream of feeling)" (p.729). These three concurrent processes create what we generally describe as emotions.

Papez defined the relationship among different subcortical formations and hypothesized that these are responsible for the upsurge of what we call emotions. This process, however, exploits the mediation of several cortical structures. The mammillary bodies represent, in his description, the interface between the subcortical and cortical areas of the emotion loop: "the mammillary body is the ultimate recipient of various afferent excitations, which reach the hypothalamus especially through the afferent centres of the ventral thalamus" (p.729). As we will review in the following sections, the role of the frontal cortex is essential in the description of the emotional processes.

2.4.2. Limitations of the Papez circuit: the extension of the limbic system.

As any pioneering study, this first description of the limbic system lacked however several regions and structures critically involved in the processing of emotional stimuli. MacLean (1949; 1952) gave a significant contribution in the first instance naming the loop as

"limbic system" for the first time (from the Latin word '*limbus'*, border, due to its shape) and then describing it in terms of both phylogenetical and ontogenetic evolution. More recent studies using modern techniques of dissection have confirmed, at the anatomical level, what was hypothesised by Papez in the description of the limbic system (Shah, Jhawar, & Goel, 2012).

Along with this basic loop, further components have been found implied in emotional processing and progressively added to the system (Fig. 4 and 5).

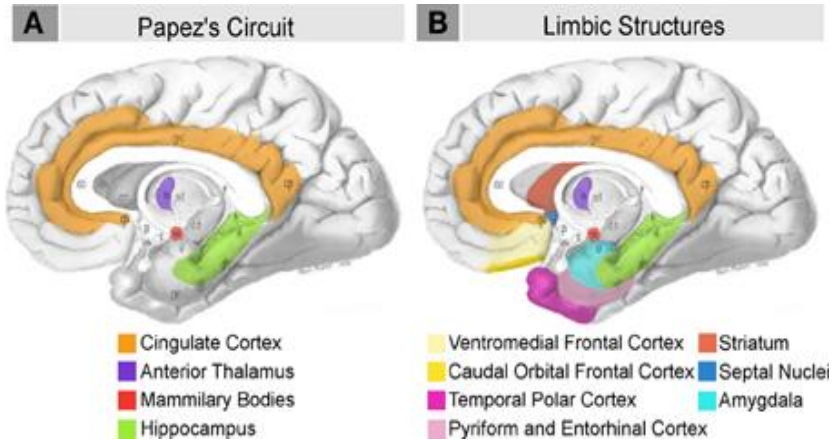


Fig. 4 – Comparison between the original Papez circuit (A) and the structures later added to the limbic system (B) (Image from Barger et al., 2014).

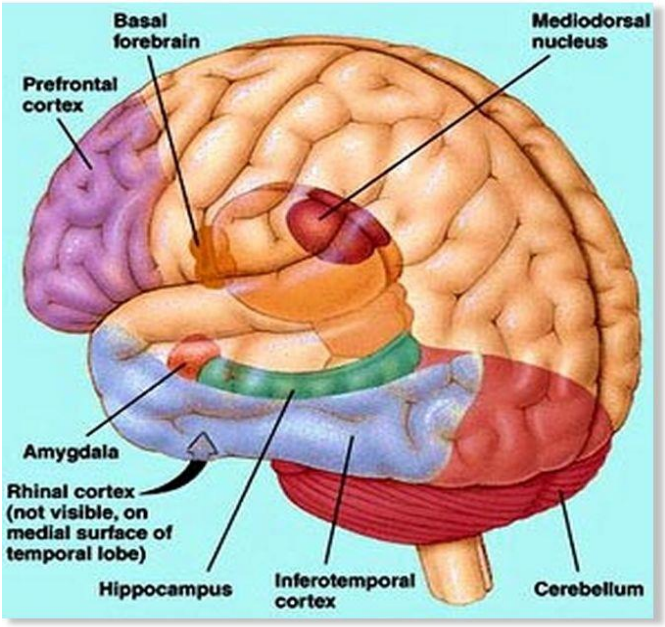


Fig. 5 – The other areas found involved in the processing of emotional stimuli.

The amygdala, almond-shaped structure, has been found active in the response to fearful stimuli and playing a prominent role in emotional learning and modulation of the response to emotional cues. This result is consistent in animal as well as human studies, both in clinical (lesion studies) and control (neuroimaging) populations (Phelps, Ledoux, Place & Place, 2005).

The insula contributes to the response to pain (and in general in the perception of painful stimuli) in the healthy population (Casey et al., 1994).

The cerebellum is also involved in emotional processing (Snider & Maiti, 1976). The authors performed a variety of experiments, including neurohistology, electrophysiology, electrically induced after-discharges, and animal behavioural studies. They pointed out how the cerebellum is interconnected with several structures composing the limbic system (ventral tegmental area and periaqueductal gray areas among the most relevant). In addition,

its activity can influence one of these structures: stimulation of the cerebellum, in fact, causes discharge waves in the hippocampus and lateral amygdala. These results have been successively confirmed by more recent studies, pointing out how lesions to the vermis can impair mnemonic recall of emotional stimuli, not altering, however, any other function of the structure as motor-related responses to affective stimuli, in particular fearful (Strata, Scelfo & Sacchetti, 2011). This effect is especially predominant for –but definitely not limited to- the perception and recall of fearful stimuli.

A meta-analysis by Frank and colleagues (2014) on the fMRI studies run between 1994 and 2014 investigating emotionally salient areas confirmed the activity of most of the subcortical regions mentioned above. They found a significant contribution of amygdala, hippocampus, parahippocampal gyrus, pars opercularis and several other structures to both emotional upregulation and downregulation processes.

Among the aforementioned areas, the case of the cerebellum is a dazzling example of how a single structure can have a prominent role in both emotion-related and pure cognitive processes. Although crystal-clear nowadays, this idea has been challenged in the past decades: the limbic system has been long seen as a series of brain areas responsible for the pure processing of emotional states, an "emotional brain" that does not share any link (anatomical or physiological) with other 'cognitive regions'. However, this case is not isolated: as we will review in the following section, other cortical areas that share the same relevance in both cognitive and affective processes.

2.4.3. The contribution of the cortical structures to emotional processing.

More recent neuroimaging studies highlighted the importance of the cortical areas, traditionally associated with pure cognitive functions, in the processing of emotions. While Papez included the cingulate cortex in his limbic system, other areas, belonging especially to the frontal and prefrontal associative regions, play a fundamental role in the emotion-related activity (Fig. 6). The most important regions involved are the prefrontal cortex and the anterior cingulate cortex. These are represented in green and yellow (prefrontal cortex) and blue (anterior cingulate cortex) in the picture.

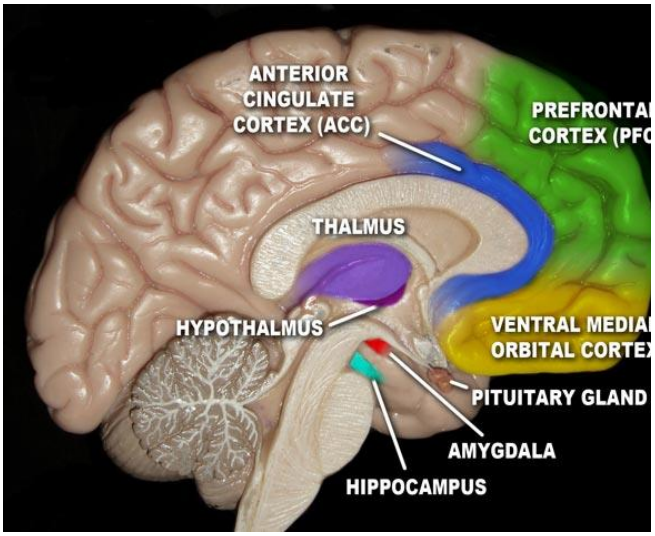


Fig. 6 – Cortical areas involved in emotional processing.

Rudbeck and colleagues (2008) reviewed the prominent role of the Orbitofrontal cortex (OFC) in the processing of emotional stimuli, especially in the context of social emotions. The OFC shares projections with amygdala and hypothalamus and its activity has been linked with the rapid, flexible modulation of emotional inputs

from several different modalities (olfactory, gustatory, tactile stimulation). This activity has been studied not only through neuroimaging experiments on healthy participants but especially through lesion studies in which the damage of the OFC produces changes in both emotional processing and social behaviour: well known, in the literature, is the case of Phineas Gage (Harlow, 1993).

A very similar work by Gasquoine (2013) illustrated the contribution of the anterior cingulate cortex (ACC) to the processing of emotions. Through analogue methodologies (review of lesion studies on clinical population and neuroimaging studies on healthy controls), he suggested how the ACC is involved in the encoding of both pleasant and unpleasant stimuli and in the mnemonic retrieval of emotionally salient episodes. The ACC shares anatomical links with the amygdala and the thalamic nuclei and its activity is often associated with the perception of emotional facial expressions in the healthy population and with an increased state of apathy in the clinical one (lesion studies).

Other areas of the cortex have also been linked to the processing of emotions, particularly due to the numerous connections they share with the subcortical structures of the limbic system (see for review Szily & Keri, 2008). For example, the ACC has extensive connections with the amygdala, anterior insula, orbitofrontal cortex, mediodorsal and anterior thalamic nuclei, nucleus accumbens, and autonomic brainstem regions. The OFC has thalamic input from the mediodorsal nucleus, which receives afferents from the amygdala. The caudal part of the OFC receives direct projections from the basolateral nucleus of the amygdala and has olfactory, gustatory, somatosensory, visual afferents. The OFC sends efferents to the hypothalamus, basal ganglia and

brainstem and projects back to the amygdala and anterior cingulate cortex.

2.4.4. Cortical and subcortical structures simultaneously interact during the processing of emotions.

The activity of cortical and subcortical structures, however, is in general not consequential, but rather simultaneous, sequential and even, for some aspects, autonomous. Morgane and colleagues (2005) reviewed, in an outstanding paper, the contribution of each subcortical and cortical region to the processing of emotions, dividing them into several subsystems with anatomical and physiological attributes. In their view, the limbic system comprises "the hippocampal formation, amygdaloid complex of nuclei, hypothalamus, nucleus accumbens, cingulate cortex, ventral tegmental area, major areas of the prefrontal cortex and limbic midbrain areas […] including the nucleus raphe dorsalis, nucleus raphe medianus, central gray, and dorsal and ventral nuclei of Gudden." (p. 146). Their description merges into a single system all the components of the core limbic system, as originally described by Papez, with the other regions subsequently added to the loop and described in the above sections. The structures included in their loop have been analysed not only in terms of activity in response to emotional stimuli but also in terms of anatomical connections with the other structures of the system. In fact, these areas are no longer considered autonomous at a functional level, but interacting in order to cope with the different psychological functions, emotion uprising included. These networks can be studied through the neurotransmitters that excite or inhibit a neural population but also, especially for the ones encompassing

the hippocampal formation, analysing the specific rhythmic oscillations, particularly in the theta band (Buzsáki et al., 2002).

Similarly to Morgane, Kober and colleagues (2008) reviewed in a meta-analysis paper over 150 neuroimaging studies dealing with the broad concept of emotion (i.e., without specifying which emotion has been taken into account in the specific study) performed between 1990 and 2005. They highlighted six different networks that appear to be consistently active during the processing of emotions. Two are lateral cortical networks, encompassing several areas of the temporooccipital cortex. Two are inner cortical networks (including portions of the premotor areas, the frontal gyri and the cingulate cortex). Two are deeper networks (which include several paralimbic structures like the insula and the striatum, along with the core ventral portions of the limbic system, as the amygdala and the thalamus). The networks presented create a neat link between the phylogenetically older areas of the brain and the neocortical areas, a prerogative of the human species. In fact, the deeper networks have been detected in other animals as well, while the cortical ones respond to emotional stimuli almost exclusively in the human brain. The simultaneous activity of all these networks during the processing of emotional stimuli highlight how the two phylogenetically distant parts of the human brain are functionally wired together. A bond that could in principle explain how animal studies on emotions (the most famous ones deal with fear conditioning, see LeDoux, 2000) can help to better understand human emotions. And a further argument supporting the claim that the separation of an emotional brain to the cognitive brain, in terms of active areas, would not accurately describe the complexity of the interaction between the two domains of emotion and cognition.

2.4.5. Two different functions within the same system: emotion and memory.

This simultaneous presence of cognitive and emotional functions within the same structures has led researchers to investigate other possible roles of the limbic formations. As described in the previous section, different cortical structures, which were thought to participate only in cognitive processing, are actually involved in the perception and response to emotionally salient stimuli. In parallel, several subcortical structures, also included in the limbic system, participate in cognitive processes. Therefore, the limbic system should not merely be regarded as "the emotional brain", since it is also involved in other cognition-related processes. Rolls (2015) pointed out how the limbic structures composing the Papez circuit contribute to two different systems, one dealing prevalently with emotions, and a second one coping with processes involving memory and spatial functions. The former includes anterior limbic structures (for example the amygdala and the orbitofrontal cortex) and evaluates in a top-down fashion the perception (from vision, olfaction and audition in the first instance, reinforced from touch and taste), generating an emotion-related output, with contribution from reward-related and decision-making processes. The latter instead encompasses the posterior limbic structures (posterior cingulate cortex, hippocampus, the posterior thalamic network among the most relevant) and has a stronger effect on mnemonic processes and spatial location, receiving information from the neocortical areas with similar functions and gathering these to produce a feedback-like, associated information. The two limbic systems are described as independent not only anatomically but also functionally: each system appears to be involved in only one of the functions and the respective structures do not take part in the functions of the other system.

The same systems are involved in the emotional experience not only when stimulation is external, but also in situations of mnemonic recall of emotional events (Damasio et al., 2000). In fact, structures like insular cortex, somatosensory cortex, cingulate cortex and the subcortical nuclei and the hypothalamus all participate to the brain activity in situations of self-generated emotional states, independently from the specific type of emotion recalled.

The involvement of the associative areas has led scientists to think whether the expression of emotions can be constricted into a single set of brain regions or, rather, involves wider networks than the simple limbic system (albeit considering all the anatomical afferences and efferences).

Moreover, it has been questioned whether it is possible to draw a specific brain circuit for any emotion (basic or complex), with its own specific areas involved at a particular temporal stage of the emotional experience. Esslen and colleagues (2004) tested this hypothesis using neuroimaging data (electroencephalography, EEG) and source reconstruction techniques (LORETA) to determine the individual signature of emotions and the potential presence of a common cerebral substrate for the expression of different emotions. They successfully highlighted how the prefrontal cortex and the cingulate cortex (anterior and posterior) are part of a network in the brain neocortex involved in the emotional experience, independently from the specific one. This study confirms what previously found by George and colleagues (1995) in a PET study in which both temporal lobes showed significant activity in non-specific emotional processing induced by the display of emotional faces.

Single emotions have however their own unique features, as shown for example by Damasio and colleagues (2000). In their

PET experiment, participants were asked to reappraise personal experiences giving rise to either sadness, happiness, anger or fear: each displayed specific activation, in both superficial cortical areas and deeper subcortical regions.

The definition of a possible network, at the cortical level of the brain, active in the broad emotional experience, has been the target of a wide stream of research during the last few decades. Nevertheless, the response of the cortical areas to the emotional stimuli is not homogeneous: in fact, some specific areas play a pivotal role in the emotional processing.

2.5. The frontal cortex in the processing of emotions: frontal asymmetries and theories explaining the neural patterns of activation.

The frontal cortex, in particular, plays a distinctive role in this context. This associative area has been tightly linked with the valence of an emotion: each hemisphere, in fact, appears to respond to a specific valence level, in an asymmetrical fashion. A plethora of studies, illustrated within this section, have confirmed this postulation, either contrasting positive and negative stimuli in the same design or focusing on a single emotion and describing the cortical (sometimes along with the subcortical) activations related to it. However, in some cases, the study of single emotions has provided inconsistent results. For example, both Breiter et al. (1996) and Sprengelmeyer et al. (1998) designed an fMRI paradigm inducing fear in the participants through the same emotional stimuli –human faces retrieved from the Ekman database (Ekman, 1975). They found activations in different areas: while in the former the amygdala played a pivotal role, in the latter the majority of the activations were comprised within the frontal

cortical areas. Due to these –and many other similar- inconsistencies, the most widely used approach to study these asymmetries has been to classify emotions (and the related stimuli) into two sub-categories according to the level of valence, either positive or negative and link each one with the activity of the frontal areas.

2.5.1. A first theory for the frontal asymmetries: the right hemisphere hypothesis.

These studies have been initially performed at the beginning of the last century and dealt in particular with a clinical population suffering from hemiplegia or from damage to a single hemisphere (Goldstein, 1939). Researchers highlighted how impairments to the right hemisphere caused higher levels of apathy, while damages to the left one were associated with higher inabilities to control emotional states and reactions. This led to thinking that the frontal cortex had specialised functions which differed in the two hemispheres, the right one highly involved in emotional processing, regardless of the "colour" (valence) of the emotion and the left one specialised instead in the cognitive control of emotion and, in general, in cognitive-driven activity. This "right hemisphere hypothesis" was not new even a century ago and has received support even in recent years (Smith & Bulman-Fleming, 2004, 2005). These studies showed how both consciously and unconsciously (i.e. subliminal) processed emotional stimuli led preferentially to the activation of the right hemisphere independent of their valence. Along with evidence from neuroimaging experiments, the theory found support from behavioural studies (Sackeim, Gur & Saucy, 1978). These pointed out how people rated as more emotionally salient the facial expressions displayed in the left half of the face, in comparison to the right. As the

contralateral projections from a hemisphere are in control of the musculature of one-half of the face, researchers concluded that the emotional features (leading to the display of the emotions through facial movements) are more salient in the right, compared to the left, hemisphere of the brain. The same line of reasoning has been applied to auditory stimulation, through experiments on both clinical population and healthy controls in which emotionally salient sounds (laughs, cries, etc.) have been administered unilaterally to the left or the right ear (Borod, Andelman, Obler, Tweedy & Wilkowitz, 1992; Carmon & Nachshon, 1973). Stimuli presented on the left side benefitted again from a significantly more accurate classification in comparison to the ones played in the right ear of the participants, regardless of their valence.

2.5.2. A stimulus-driven lateralization: the valence hypothesis.

In parallel, another wealth of studies disagreed with the right hemisphere hypothesis and proposed that both hemispheres are equally involved in the processing of emotions, with an asymmetry brought in by valence. In fact, according to the "valence hypothesis", the left hemisphere appears specialised in the processing of positive stimuli, while the right one becomes active in response to stimuli provoking negative emotions (Hellige, 1993). Pioneering in the field was the research by Davidson and colleagues (1979), who analysed EEG activity at both frontal and parietal sites in response to movie clips prompting positive and negative emotions. While the parietal channels did not show any lateralization effect, the frontal ones registered an increase in the activity for the left hemisphere in response to positive clips and for the right one in response to the negatives. This pattern of activity appears to be present since the birth of a person (Fox & Davidson,

1986). EEG activity and facial expressions recorded in 2 days old newborns in response to tasting water with sugar or lemon elicited expression of disgust (the latter) and pleasure (the former), along with the previously illustrated pattern of asymmetry at brain level in the frontal areas.

2.5.3. The support from neuroimaging studies: involvement of the theta and alpha rhythms.

Taking a step further, recent works have attempted to link this asymmetric activity to particular neural rhythms. The vast majority of the current literature agrees on the prominent role of the Theta (4-6 Hz) and Alpha (6-13 Hz) frequency bands in the processing of emotional stimuli at frontal sites (Aftanas, Varlamov, Pavlov, Makhnev & Reva, 2001; De Pascalis, Cozzuto, Caprara & Alessandri, 2013; Schmidt & Trainor, 2001; Tandle, Jog, Dharmadhikari & Jaiswal, 2016). These two bands –and Alpha in particular- are considered the most relevant brain rhythms involved in the processing of emotional stimuli, particularly in the frontal areas. Therefore, the analysis of these frequency bands would unveil the cerebral mechanisms involved in the processing of emotional stimuli. The two frequency bands, however, operate in a different way: while theta is an active rhythm (the band power increases with the increase of the brain activity), alpha is a relaxation rhythm, with its power decreasing with increased brain activity (an effect known as alpha rhythm suppression). At the neural level, this phenomenon is explained in terms of synchronization and desynchronization of the neural population of the frontal cortices. The simultaneous firing of clustered neurons at a given rhythm generates an increase in the band power, while the random, independent activity of each component of the neural

population generates a disruptive effect of the resting condition and therefore is interpreted as increased activity.

Even differing in terms of the stimuli employed, the previously cited works adopted in all cases a similar experimental paradigm: participants were asked to passively view emotionally salient stimuli (pictures, sounds, movie clips, etc.) and EEG traces were recorded to analyse the response to them. Similar results supporting the valence hypothesis have been obtained using fMRI instead of EEG, exploiting similar experimental paradigms (Dolcos, LaBar & Cabeza, 2004; Herrington et al., 2005).

2.5.4. The motivational aims and the role of the individual: the behavioural systems theory.

Along with the valence hypothesis, another line of research aimed to explain the frontal asymmetries changing the point of view from the emotion itself (or the stimulus conveying it) to the reason that makes an emotional state arise. In other words, it analysed the *motivational* side of emotions: from a purely evolutionary theory, a stimulus can create in the perceiver either a sense of *approach* towards it, or one of *withdrawal*. This concept has been classically described in the animal world as the "fight or flight" behaviour, according to which an animal can approach a stimulus essential for survival (i.e. food available) or withdraw from this engagement (i.e. running away from a predator). Emotional stimuli (and emotions in general) are particularly salient for survival -fear is probably the most renowned example-, and would, therefore, activate these mechanisms. Hans Eysenck and Jeffrey Gray attempted a description of two possible antagonist systems responsible for the processing of emotional stimuli from a motivational perspective (Matthews & Gilliland, 1999).

According to Eysenck, two different neural ways originating from the reticulum and comprising respectively cortical and limbic areas respond to the level of arousal deriving from an external stimulation (the former) and the response to emotional stimulation (the latter) (Eysenck, 1963; Eysenck & Eysenck, 1985). Therefore, emotional stimuli would activate the limbic system and this activity would reverberate onto the frontal cortical areas controlled by the first pathway. Two distinguished individual traits, treated as orthogonal variables, described in his formulation the activity of the two pathways: Neuroticism and Extraversion, respectively linked to the limbic and cortical pathway. Eysenck mainly grounded his theory on behavioural measures like self-reported questionnaires and provided weak links between psychological and physiological measures (Eysenck & Eysenck, 1975; Eysenck & Eysenck, 1994). Even the description of the two pathways, on which his theory is grounded, appears vague and generic.

Gray, Eysenck's PhD student, took the moves from his supervisor's theory, disagreeing however on the methods that led to the creation of the Neuroticism-Extraversion plan. Gray relied more on physiological studies, especially involving animal testing, and tried to establish a stronger bond between physiological responses and motivational behaviour (Gray, 1981). In his Reinforcement Sensitivity Theory (RST), which underwent a major revision at the beginning of the millennium, he theorized the existence of two different variables, Impulsivity and Anxiety (Gray & McNaughton, 1982; McNaughton & Gray, 2000; Pickering & Corr, in Boyle, Matthews & Saklofske, 2008). These are described as mutually orthogonal, 30° anticlockwise rotated with respect to Eysenck's N-E axes (Impulsivity corresponding to Extroversion, Anxiety to Neuroticism) and associated with two different, mutually exclusive Behavioural Systems, the Inhibition (BIS), activated by

punishment-driven stimuli, and Activation (BAS), stimulated by reward-driven elements (the latter is sometimes referred as Approach System). Specifically, the dimension of Impulsivity has been linked with the Activation system, while the Anxiety with the BIS. The two systems are responsible for the asymmetries present in the frontal cortex in response to the emotional stimuli: in particular, the BAS is hypothesized to control the left hemisphere, while the BIS would be in control of the right one. Hence, according to the RST, the activity of the frontal areas in response to emotional stimuli can be explained on purely motivational bases: a stimulus generating approach-driven tendencies, as happiness does, for example, would activate the BAS, while stimuli generating withdrawal-driven tendencies, like disgust, would activate the Inhibition system. Other than complementary, the two systems are described as mutually exclusive: each person would, in fact, display a more or less consistent physiological dominance of one of the two systems (Demaree, Robinson, Everhart & Youngstrom, 2005; Matthys, van Goozen, de Vries, Cohen-Kettenis & van Engeland, 1998). This dominance can be established by the means of resting-state activity analysis from neuroimaging sources; a correlation analysis between brain activity in response to emotional stimuli and self-reported measures of BIS/BAS dominance would allow an association between the two measures. A different individual sensibility would be translated into individual differences in the processing of the same stimulus because of a heterogeneous degree of dominance of the behavioural systems (Balconi, Grippa & Vanutelli, 2015; Coan & Allen, 2004).

2.5.5. A comparison between the valence hypothesis and the RST: the case of anger.

Several studies attempted to compare –and possibly reconcile- the valence hypothesis and the RST, giving partial support to Gray's theory, although failing to completely reject the valence hypothesis (Krpan & Schnall, 2014; Miller, Crocker, Spielberg, Infantolino & Heller, 2013; Van Honk & Schutter, 2006; Wager, Phan, Liberzon & Taylor, 2003). These works highlighted how the motivational features, more than the valent ones, would drive the lateralized activity of the frontal cortices; yet, while this result appears more stable for the left hemisphere, it is still questionable for the right one, which does not display a clear characterization in the processing of withdrawal-driven stimuli. It is worth noting, however, how the vast majority of the studies supporting the valence hypothesis has systematically left outside individual personality traits from their analysis, which are instead fundamental in Gray's theory.

The best support for the RST against the valence hypothesis derives from the work of Harmon-Jones and colleagues studying the processing of anger (Harmon-Jones & Allen, 1998; Harmon-Jones, Gable & Peterson, 2010). Anger, "the driving force of humanity", is considered a negative-valent emotion, but has approach-driven features: according to the RST, it should then generate a stronger activity in the left hemisphere, while according to the valence hypothesis, the stronger activity should be present in the right frontal areas. The predominant involvement of the left, compared to the right, hemisphere in response to stimuli generating anger, calculated by the mean of relative alpha band power suppression via EEG recordings, supported RST over the valence hypothesis. Since then, the RST has been corroborated by several studies (Balconi & Mazza, 2009; De Pascalis, Cozzuto,

Caprara & Alessandri, 2013; Diego, Field & Hernandez-Reif, 2001), which highlighted a pattern of asymmetrical activity in response to emotional stimuli coherent with the hemispherical specialization of the two behavioural systems.

As already postulated at the physiological and anatomical level, the relevance of the motivational direction in emotion has led to the almost complete rejection of the idea of an isolated emotional brain in favour of an integration between emotional and cognitive functions within the same regions. The rise of the cognitive-emotional brain theory is a new, almost unexplored path in the field of cognitive and affective neuroscience (Dolcos, Wang & Mather, 2014; Pessoa, 2013). For this reason, it is essential to clarify how the emotional and cognitive processes are related, in order to establish a link between the two domains that can help the conceptualization of the cognition-emotion interplay.

3. The interaction between emotional and cognitive processes.

"You learn emotional experiences as much as you learn cognitive experiences, except that they are more unconscious. Sometimes one represses the cognitive component of it, but it's often more difficult to repress the emotional component." (Eric Kandel).

As several different authors pointed out, neuroscientists are called to define the fundamental elements of the interplay between cognitive and emotional processes, in the attempt of describing the mutual interactions across the two domains and establishing the biological bases for the new concept of the cognitive-emotional brain (see for review Okon-Singer, Hendler, Pessoa & Shackman, 2015; Pessoa, 2008). This innovative framework must contemplate two different approaches, both vital: on the one hand, outline the neural networks possibly responsible for the mediation of the processes in the different realms, taking into account long-range networks rather than single, isolated structures, as it was commonly done in past research (Barrett & Satpute, 2013; Kinnison, Padmala, Choi & Pessoa, 2012). On the other hand, characterize a behavioural approach to the problem, in order to better describe the perception-action loop and, possibly, add the "emotion" variable to it, explaining the mutual relationships across the elements (Pessoa, 2017).

Nowadays, it appears impossible to disentangle completely emotion and cognition, as both show reciprocal effects on the other domain. Blair and colleagues (2007) showed in an fMRI study how the presence of emotionally salient, task-irrelevant pictures can affect the completion of an ongoing cognitive task (numerical recognition task). Conversely, the ongoing task

influences the perception of affective stimuli by reducing the BOLD signal in the regions deputed to their processing.

Although remarkable for the fine quality of the design, this study is not a meteor in the sky of the emotion-cognition interplay research. A plethora of studies has attempted to establish whether one domain affects more consistently the other, in an effort to state whether any of them is subsided to the other (see for review Dolcos, Iordan & Dolcos, 2011; Storbeck & Clore, 2007).

3.1. Cognition influences emotion.

The influences of cognition on emotion have been mainly studied by the means of cognitive regulation or reappraisal of emotional states, often using functional imaging techniques. Cognitive regulation of emotion has classically been described as a multifaceted process: it refers, in general, to the use of cognitive strategies to control, more or less consciously, the emotional states perceived (Gross, 1998).

Three of the most common schemes described in the literature are distraction, reappraisal and labelling (McRae, 2016; Moyal, Henik & Anholt, 2014). The first refers to the change in the focus of attention from an emotionally intense stimulus, reducing in this way the effects of emotional stimulation. This mechanism of emotional suppression, that leads to an alteration in the activity of several areas deputed to the affective processing, like the frontal cortex, contemplates the non-attendance to the emotional stimulus, unlike the following two strategies (Jackson et al., 2012). Reappraisal, in fact, consists of the conscious explanation of an emotional situation, a description that can reduce the effects of emotional states. Finally, labelling has been described as the verbal processing of emotional states, differing from reappraisal in

the sense that the former holds a more *descriptive* meaning, while the latter relates to *identification*. The effects, however, are similar: labelling as well brings to a reduction of the subjective emotional arousal.

In all the three mechanisms, by "reduction of emotional states" is meant the decrease in the activity of the structures involved in the expression of emotions, measured by the means of imaging techniques (fMRI in particular). This reduction is particularly pronounced in the presence of negative emotions, where the decrease of activity in regions such as the amygdala, the insula and the prefrontal cortex has been consistently described (see for review Buhle et al., 2014; Ochsner & Gross, 2008).

Moreover, Ochsner and colleagues (2002) reported, along with the aforementioned decreased activity of the amygdala, an increased activity of several areas of the medial and lateral prefrontal cortex, determined via an fMRI study involving a reappraisal of feelings elicited by the presentation of negative pictures. They interpreted it as an increase in the involvement of the areas deputed to cognitive control, exerting a feedforward regulation over the areas responsible for the emotional expression. This result has been successfully replicated by other fMRI studies, with similar experimental setups (Mulej Bratec et al., 2015; Otto, Misra, Prasad & McRae, 2014; Xie et al., 2016). Self-reported measures, along with neuroimaging data, have described the cognitive control of emotions as a positive factor in the framework of individual well-being (Hoorelbeke, Koster, Demeyer, Loeys & Vanderhasselt, 2016). Reduction in the levels of stress and anxiety have been described in several works (Aldao, Nolen-Hoeksema & Schweizer, 2010; Cutuli, 2014; Goldin & Gross, 2010).

3.2. Emotion influences cognition.

3.2.1. The automatic Vs competitive theories over the influence of emotion on cognition.

In parallel to this body of studies, another stream of research attempted to define how emotion could affect cognitive processes. Two competing theories try to explain this influence: one stating that it is *automatic*, as emotional stimuli are prioritized independent of any other cognitive process ongoing (therefore, any emotional stimulus would influence cognition) (Dolcos, Iordan & Dolcos, 2011). Another asserted that the influence is *competitive* with regard to the attentional resources available (therefore, emotion can influence cognition by subtracting a share of the attentional resources from an ongoing cognitive process). The two theories disagree on the idea of "attentional resources available": in fact, if the full set of attentional resources is not engaged by a highly demanding cognitive process, it is easily predictable that the emotional stimuli can engage the remaining part, therefore appearing as an automatic (prioritized) processing of the stimulus rather than a parallel one. Pessoa and colleagues (2002) demonstrated how task-irrelevant but emotionally salient elements did not generate a strong activity in the regions deputed to emotional processing (like the amygdala in response to fearful stimuli) when the cognitive demands are high. Instead, the activity in the amygdala increases the moment the stimuli become attended during a cognitive task (gender recognition on fearful Vs neutral faces).

3.2.2. How emotions influence goal-directed behaviour.

Emotions can also influence two fundamental dimensions of goal-directed behaviour, such as working memory and decision-making.

Influences on working memory have predominantly been studied by the means of emotional distraction. Task-irrelevant emotional stimuli have been seen to reduce activity in the dorsal cognitive network, deputed to the processing of cognitive tasks, while simultaneously increasing the activity of the ventral network, deputed to the processing of the emotional stimuli (Chuah et al., 2010; Dolcos & McCarthy, 2006; Fuster, 1997). The effects of emotional distractors on task performance will be extensively described in the following sections of the chapter.

Influence on decision making has been classically linked with the motivational features of emotional stimuli (Damasio, 1996; Heimer & Van Hoesen, 2006). Structures profoundly implicated in affective processing such as the amygdala and the ventromedial prefrontal cortex (VMPFC) would create a feedback mechanism in tasks affectively and motivationally salient –as the Iowa Gambling Task (Bechara, Tranel, Damasio & Damasio, 1996). Emotion-driven processes can, in fact, lead to the selection of better, more rewarding strategies in decision-making tasks, as well as improve abilities in adapting behaviour during the completion of a task, to seek the best possible outcome.

Confirmation of this hypothesis came from functional imaging studies (Sanfey, 2003). The activation of the ventral system (the insula, in particular, deputed to the processing of disgust) displayed significantly higher activation in response to choice tasks contemplating an unfair (compared to a fair) option in the splitting of a set amount of money (for a review on the topic, see Rilling, King-Casas & Sanfey, 2008). Further evidence comes from lesion

studies, in which the same task has been proposed to patients with damage to the aforementioned areas: they displayed poorer judgement abilities and lower scores in self-reported measures of emotional intelligence recorded along with the task, in comparison to healthy controls (Bar-On, Tranel, Denburg & Bechara, 2003).

One last interesting, perhaps slightly extreme, perspective on the influences of emotion on cognition is provided by Inzlicht and colleagues (2015) according to whom cognitive control is nothing but an expression of emotion. In this view, emotion and cognitive control are not two interacting systems but a logical and causal chain. Cognitive control would, in fact, arise in the presence of a conflict (discrepancy between realistic expectations and actual behaviour), which in turn is nothing but affectively aversive perception, therefore belonging to the negative emotions spectrum. This theory is in line with the body of research that considers the Behavioural Inhibition System as a conflict detection system, more than a withdrawal-related one, and would become active in the presence of a conflict and not in response to any negative affective stimulus (Berkman & Lieberman, 2010; Corr, 2013).

Along with this qualitative analysis, the influence of emotion on cognition has also been evaluated quantitatively, through behavioural and neuroimaging studies. However, the effects have not been defined univocally (see for review Dolcos & Denkova, 2014).

3.3. How emotion influences cognition: enhancing or detrimental effects?

3.3.1. The enhancing effects of emotion on cognition.

While a path of research highlighted how emotional stimuli can have a beneficial effect on ongoing cognitive processes, another body of studies outlined the impairing effects of emotion on cognition.

With regard to the former, enhancing effects have been evaluated in terms of perception and episodic memory. Perceptually, the detection of emotional stimuli (in comparison to non-emotional ones) allows achieving significantly faster and more accurate responses to a concomitant task (Pourtois, 2004; Santesso et al., 2008). For example, angry faces, compared to neutral ones, presented as distractors preceding a task (judgement over the orientation of a bar, horizontal-vertical), generate faster and more accurate responses to the task itself; this improvement at the behavioural level is supported by increased activity in the amygdala and prefrontal areas deputed to emotional control (see for review Sergerie, Chochol & Armony, 2008). Other studies supported this claim by suggesting how, in patients with unilateral or bilateral damage to the amygdala, the advantage from the presence of emotionally salient elements on task performance is absent (Gläscher & Adolphs, 2003).

Episodic memory benefits from the presence of emotional processing as emotionally salient stimuli are generally remembered more vividly in comparison to non-emotional ones (Comblain, D'Argembeau & Van der Linden, 2005; D'Argembeau, Comblain & van der Linden, 2003). In free recall of autobiographical memories, emotionally salient situations (either positive or negative) received

a higher definition of details compared to non-emotional ones. Moreover, emotional memories have been found to generate a stronger electrodermal response and higher cardiovascular activity during the free-recall process in comparison to non-emotional ones (Schaefer & Philippot, 2005).

This enhancing effect has been detected not only for autobiographical memories but also from external stimulation, by the means of passive observation and subsequent recall of emotionally salient Vs neutral stimuli. fMRI studies reported increased activity in regions crucially involved in the processing of emotions, as the amygdala, mediotemporal lobe and prefrontal cortex, in the presence of emotional stimuli, not only in the encoding phase but also in the retrieving one (Shafer, Iordan, Cabeza & Dolcos, 2011). These regions, however, appear to have a different role in emotional encoding: while the amygdala is highly involved in the immediate, perceptual phase of the process, the prefrontal areas play a pivotal role in the deeper processing of the stimuli and the subsequent storage in memory (Ritchey, LaBar & Cabeza, 2011). With regard to the stimuli properties that drive this enhancing effect, arousal appears to be a better modulator compared to valence: high-arousing stimuli are more easily remembered and recalled compared to low-arousing ones, independently from the valence level (Murty, Ritchey, Adcock & LaBar, 2011).

3.3.2. The impairing effects of emotion on cognition.

Influence of emotion on cognition, however, can also have detrimental effects due to the distracting power of emotional stimuli, when used as task-irrelevant elements. Through functional imaging techniques, Shafer and colleagues (2012) suggested that emotional distractors, compared to non-emotional ones, led to

increased RTs in response to an ongoing task (in the specific case, discrimination of the orientation of a picture, whether landscape or portrait). Moreover, they highlighted how the prefrontal cortex, in particular, can be the cerebral area that most responds to emotional distraction, increasing its activity in the presence of distractors: an increase that correlates with higher task RTs. Other studies investigating emotional distraction confirmed the findings illustrated, detecting an increase in RTs in response to trials containing emotional distractors in comparison to non-emotional ones (Vuilleumier & Driver, 2007; Vuilleumier, Armony, Driver & Dolan, 2001). This detrimental effect holds true independently of the consideration that emotional stimuli would receive prioritised processing or special allocation of attentional resources (Pessoa, 2005).

With regard to the impairing effects on working memory, the paradigm adopted in several studies is the Sternberg delayed response task (Sternberg, 1969), in which an array of elements is presented within each trial, followed by a probe stimulus (see for example Anticevic, Barch & Repovs, 2010; Denkova et al., 2010; Oei et al., 2012). Participants are instructed to determine whether the probe was part of the initial array or not. Distractors are presented between the array and the probe. Results highlighted how the presence of emotional (Vs non-emotional) distractors led to a significant decrease in task response accuracy, implying a detrimental effect generated by the emotional stimuli. This pattern has been replicated in the vast majority of the studies present in the current literature, with only a few exceptions in which emotional and non-emotional distractors led to non-significant differences in task performance (see for example Bendall & Thompson, 2015).

It must be noticed, however, how several experimental manipulations may lead to quantitative differences in the effects of emotional distractors on task performance. For example, the impairing effect of emotional distractors has often been studied by contrasting single-valent emotional stimuli (i.e. either positive or negative groups of distractors) against a neutral control condition. When contrasting directly the two different valence levels, results are not homogeneous.

3.4. The effects of valence in the emotional distraction.

3.4.1. Positive and negative emotional distractors have similar effects on task performance.

In the current literature, there is no consensus on the role of valence in the field of emotional distraction: while a path of studies reported similar effects of positive and negative stimuli, others instead detected significant differences.

To the first group belong several neuroimaging studies and behavioural experiments (Aquino & Arnell, 2007; Hindi Attar, Andersen & Müller, 2010; Lane, Chua & Dolan, 1999; Schulte Holthausen, Regenbogen, Turetsky, Schneider & Habel, 2016; Straube, Pohlack, Mentzel & Miltner, 2008; Wiens & Syrjänen, 2013). They support the hypothesis of the absence of differences between positive and negative distractors on task performance. The studies mentioned adopted different experimental designs to analyse the phenomenon of emotional distraction.

Among them, particularly interesting is the work from Schulte Holthausen and colleagues, who maintained a congruency between task and distractor type, asking the participants to determine the

emotion conveyed by a target face flanked by other distracting faces (either positive, negative or neutral). They did not find, however, any significant difference across distracting conditions in response accuracy nor in RTs. Importantly, this effect was found to be invariant whether the distractors are presented simultaneously with the targets or with a delayed presentation between the two elements (distractors presented before the targets).

It is also worth mentioning the work from Straube and colleagues, who used fMRI to study the effects of a distracting picture in the background on a simultaneously presented task superimposed to the picture (detection of the orientation of a bar, either vertical, horizontal or diagonal). Despite the lack of significant effects of the valence of the distractors, they pointed out significantly higher activation of the amygdala in response to negative distractors than positive and neutral (which in turn did not display significant differences). The study highlights how crucial can be the correct selection of the task associated with emotional distraction: an oversimplified task producing a close-to-perfect performance from the majority of the participants would prevent the detection of differences at a behavioural level that, instead, might be present (and could be delineated) at the brain level.

3.4.2. Positive and negative emotional distractors have different effects on task performance.

In parallel several other studies, using again electrophysiological approaches and behavioural measures pointed out a different role for positive and negative distractors, defining a different influence on task performance (Balconi & Ferrari, 2012; Buchner, Rothermund, Wentura & Mehl, 2004; Hodsoll, Viding & Lavie, 2011; Rosen & Grandison, 1994; Thomas & Hasher, 2006). In these cases, significant differences in terms of task RTs and

accuracy were found not only between trials containing emotional distractors compared to neutral/no distractor control conditions, but also within the single levels of valence, in the majority of the cases detecting significant increase in RTs following the presentation of a negative distractor compared to a positive. These studies emphasised how positive distractors, compared to negative ones, have generally a less detrimental effect on task completion, which in turn leads to significantly higher task RTs and decreased accuracy rates.

3.4.3. A possible explanation for this discrepancy: methodological limitations of the studies present in the current literature.

The analysis of the latest literature proposed, along with several other less recent works, highlights a vast discrepancy in terms of the effects of the distractors' valence. However, several experimental manipulations, which have been systematically overlooked, could in principle account –at least partially- for the variance of the current findings.

In primis, across the various experimental designs, the distractors selection was homogeneous only on the valence dimension, while varying more in arousal. If not carefully controlled, effects (or lack of effects) of distractors that are imputed to valence could actually be driven by arousal.

An example is provided by Sussman and colleagues (2013), who nicely outlined a strong interaction effect between the two dimensions in the domain of emotional distraction, through an experiment in which participants were asked to detect the colour of a dot superimposed on an emotional distractor. Compared to the positives, performance in the presence of negative distractors was

significantly poorer in the high-arousing condition and significantly better in the low-arousing one.

The same result has been achieved by Fernandes and colleagues (2011), who designed a numerical parity judgement task with the two numbers to compare flanking an emotional distractor in each trial. The aforementioned valence-arousal interaction was defined for both task accuracy scores and task RTs.

Iordan and Dolcos (2015) instead, through an fMRI study involving a working memory task with neutral faces as memoranda/probe and emotional pictures as distractors presented in between, pointed out how positive distractors increase task accuracy performance. However, this result was found independent of the arousal levels of the distractors.

It is possible to notice how, especially in the case of low-arousing stimuli, the results are highly conflicting: this –and other- similar findings call for the need for a careful selection of the stimuli within an experimental design, possibly considering several parameters beyond the level of pleasantness.

Secondly, all these studies considered the valence of the distractors per se, and not in relation to the participant who perceives the stimulus. This lack of accountability for personality traits can be crucial in the definition of the effects of emotional distractors: in fact, as previously illustrated, individual measures of BIS/BAS dominance, along with measures of relevant traits as impulsivity and anxiety, have been found essential in the explanation of the processing of emotional stimuli. Therefore, in principle, the same traits ought to be analysed also in the context of emotional distraction to determine possible associative effects with differently valent stimuli.

Eventually, two other manipulations that have often been disregarded are the type of task and the type of distractors used in the experimental designs. In fact, different types of distractors (for example, emotional pictures depicting faces or scenes) or tasks that require a different cognitive load (and therefore the engagement of a different amount of attentional and mnemonic resources) might in principle lead to effects in task performance that are not related to the distractors' valence.

Several experiments have attempted to control separately these three variables (type of task, type of distractors used and individual differences in participants' personality traits), and pointed out how they can be relevant in the study of emotional distraction, without however providing a systematic, ordered measure of the effects. The following section of this chapter will illustrate the relevance of the aforementioned manipulations.

3.5. The effects of task manipulations in the study of emotional distraction.

3.5.1. Individual differences and personality traits related to emotions.

Individual differences appear to be crucial in the modulation of the response to emotional stimuli. As previously described, behavioural dominance is defined as the tendency of an individual to approach or withdraw from an emotional stimulus. Higher activation dominance underlines a higher tendency for the individual to engage the emotional stimuli, the positive in particular. A higher inhibition dominance underlines a higher tendency of the individual to withdraw from emotional stimuli, the negative in particular.

Therefore, higher BIS or BAS dominance underline higher sensitivity to negative and positive stimuli respectively.

The dominance of Behavioural Activation/Inhibition Systems can be defined directly through self-reported measures, as the Carver-White questionnaire (Carver & White, 1994) or the Sensitivity to Reward/Punishment Questionnaire (Torrubia, Ávila, Moltó & Caseras, 2001). Moreover, by definition of the two systems, BIS/BAS dominance can be measured through the two dimensions of trait Impulsivity/Anxiety respectively (Caseras, Ávila & Torrubia, 2003; Corr, 2004, 2008; Vervoort et al., 2010).

The degree of dominance of either system, evaluated behaviorally or through electrophysiological measures of asymmetric activity at the frontal cortical sites, has been extensively correlated with the processing of emotional stimuli (Balconi, Falbo & Conte, 2012; Balconi, Vanutelli & Grippa, 2017; Calder, Ewbank & Passamonti, 2011; Fales, Becerril, Luking & Barch, 2010; Gable & Harmon-Jones, 2013; Peterson, Gable & Harmon-Jones, 2008). According to these works, positive emotional stimuli would generate an activity in the left hemisphere proportional to the individual measure of BAS dominance; conversely, the activity generated in the right frontal areas by negative emotional stimuli increases linearly with the increasing level of BIS dominance. This effect, in the context of emotional distraction, has not been assessed by past research: however, being emotionally salient, valent distractors should be expected to generate an activation of the behavioural systems.

If the individual differences are not controlled, a bias in the results could in principle be present. For example, in a population sample highly BAS-dominant, the perception of positive distractors might be facilitated compared to the negative ones, therefore they could generate a weaker distracting effect, leading to differences in task

performance in the presence of positive and negative distractors. Without the measurement of these individual differences, it is virtually impossible to rule out this source of confound. That is, the ascription of any effect to the valence of the distractor on task performance *per se* and not as an effect of individual personality traits cannot be fully investigated unless individual measures of behavioural dominance are included in the analysis.

To create a parallel, behavioural dominance can be thought as similar to manual preference (handedness). Let us hypothesize that a strongly right-handed population sample is asked to perform a single-hand task with the left or the right hand, such as writing. A possible advantage in task performance can be driven either by task-related features or by the individual differences of the participants (i.e. manual preference) and if this latter variable is not controlled, then it is not possible to determine the source of the effect.

Interestingly, this similitude is much closer to reality than one can expect. In a fascinating study, Brookshire and Casasanto (2012) measured resting-state alpha activity via EEG in left- and right-handed participants, correlating the electrocortical activity with self-reported measures of BAS levels. Results displayed an inverse pattern of activity in left-handers, with the BAS system apparently modulating the activity of the right hemisphere instead of the left. The authors proposed the "sword and shield hypothesis" to explain the results: a sword, approach-related tool, is controlled with the dominant hand, while the shield, defensive-related tool, is held with the non-dominant hand. Similarly, approach system would share the same cortical hemisphere in control of the dominant hand; withdrawal system would share the same hemisphere of the non-dominant hand. Taking in mind this example, it would be essential to include, within the future experimental protocols,

measurements of hand dominance, in order to limit any possible effect driven by this factor and analyse instead its potential role in the context of the emotion-cognition interplay.

3.5.2. The influence of the type of distractor chosen.

Along with individual differences in the population, another source of variance in the study of emotional distraction is the type of stimulus used as a distractor. Limiting the analysis to the visual ones, several studies pointed out differences in the perception of various emotional elements (Hindi Attar, Andersen & Müller, 2010; Trauer, Andersen, Kotz & Müller, 2012). These works used similar behavioural and electrophysiological (Steady State Visual Evoked Potentials, SSVEP, in the example) measures to test independently the effects of different distractors (respectively, emotional pictures and words in the cited examples), finding heterogeneous effects of the two on task performance. Similar methodologies are not new in the literature, but it is evident how fallacious this approach is: a direct comparison of the two types of stimuli would be more beneficial to the correct assessment of the stimuli effects (as pointed out by Carou et al., 2011).

Other works considered specific properties of a stimulus to assess its influence as a distractor (Folta-Schoofs, Wolf, Treue & Schoofs, 2014). In the case of emotional pictures, for example, perceptually complex Vs simple pictures, irrespective of valence and arousal normative ratings, can produce different effects on task performance. Complexity has been defined as the number of elements present in the depicted scene (Cycowicz, Friedman, Rothstein & Snodgrass, 1997). In particular, less complex scenes have been found to have greater distracting power on task completion, reducing the participants' ability to correctly perform it.

In conjunction with visual complexity, control of the content of emotional pictures is essential. Olatunji and colleagues (2015) demonstrated how emotional faces and scenes have different distracting effects on task performance, with scenes (particularly for the negative valence level) producing stronger disrupting effects than faces.

From the aforementioned examples, it is essential for future research to achieve a double target to study emotional distraction. First is to carefully balance the elements chosen within a group of stimuli (for example, avoiding the use of only emotional faces only highly complex scene compositions) and, whenever possible, compare the effects of different types of distractors simultaneously, to assess the effects on task performance of each of them and establish features and differences of each type.

3.5.3. The influence of the type of task chosen and the cognitive load required.

Eventually, the type of cognitive task used to study emotional distraction can also play a relevant role.

According to a series of studies, the different cognitive load may interfere with the perception of the distractors. Gupta, Hur and Lavie (2016) pointed out how, in a search task with different levels of associated cognitive load, even using three different classes of emotional distractors (pictures, faces and faces associated with economic gain/loss), distractors' valence stably interacted with cognitive load. They found no differences across positive and negative stimuli in the low-load condition and significantly higher disruptive effects for negative distractors in conditions of high load. However, it must be noticed how between faces and scenes there is a difference in arousal values that could have affected the results and has not been fully controlled.

Similar findings were reported by Kellerman and colleagues (2012), who designed an fMRI study in which participants were asked to reproduce a given motor sequence of four (low load) or six (high load) finger taps, with a distractor presented between the encoding and reproduction phases. Results highlighted how, in the low-load condition, the positive distractors led to a slight worsening in task accuracy, while in the high-load condition, negative stimuli significantly disrupted task performance compared to both positive and neutral distractors.

These results are in contrast with what found by Hindi Attar and Müller (2012) who, in an SSVEP experiment, did not find significant differences across diverse levels of cognitive load (detection Vs discrimination task of moving dots) for negative Vs neutral distractors. Schwager and Rothermund (2013), instead, showed how the careful control of the distractors and the experimental design allows the full replication of the role of distractors with two different types of task (specifically, a visual search task and an emotional Stroop task). In both cases, task performance was less accurate when the valence of the stimuli was opposite to an induced emotional state.

The wide variety of the results presented calls for a more systematic manipulation of task demands, particularly in relation to different types of tasks. One optimal strategy would be to test the same set of distractors on diverse tasks with different cognitive demands: in this way, the assessment of the distracting properties of valent stimuli would be more homogeneous and the process would possibly reduce the aforementioned variance in the results.

3.6. The effects of emotional distractors on working memory.

The vast majority of the studies assessing the features of emotional distractors agree on the salience of the stimuli used, which are consistently remembered by the participants despite being irrelevant to the conjunct task they are completing.

Different studies assessed this effect, pointing out how emotionally salient, compared to neutral stimuli, are generally remembered more vividly (see for review LaBar & Cabeza, 2006). However, past research failed to describe uniquely the role of two different, essential parameters of this encoding process. In the first instance, the role of valence: that is, whether positive or negative stimuli are better remembered, or if the recall is unaffected by valence. Secondly, the differences related to the types of stimuli to assess whether this variable would affect the recall rate of the distractors. Long, Danoff and Kahana (2015), in a free memory recall of emotional and neutral words, found no differences between positive and negative stimuli, with both of them having significantly higher recall rates than the neutral controls. Carou and colleagues (2011), in a memory recall test on emotional and neutral words in conjunction with an auditory detection task, found similar results. However, they interpreted the lack of differences between positive and negative words on gender bases, arguing that male participants recalled better positive stimuli, while females were more accurate in the recall of negative words. Maddox and colleagues (2012) instead, found significantly higher accuracy in the recall of negative words compared to both neutral and positive, while the difference between the last two was not significant. Buratto and colleagues (2014) found a similar effect, using emotional pictures instead of words, especially for mid- and high-arousing stimuli. This last work pointed out how, once more,

the need for control of arousal levels is essential in this experimental field.

3.7. Aim of the current research and overview of the experimental paradigms proposed.

As illustrated in the previous sections, there are presently evident gaps in the existing literature focusing on the study of emotional distraction. This research project aims to provide a contribution towards the resolution of some of the above-mentioned criticalities. In particular, we directed our attention towards the following issues:

- Define the role of valence for emotional distractors. Through a direct comparison of positive and negative distractors, we aim to outline the way they influence the completion of a cognitive task. We will initially take into account only one type of distractor (in particular, emotional pictures), strictly controlling the arousal dimension, the complexity, the content and the composition of the scenes displayed.
- Define the role of attentional demands and cognitive load within the cognitive task associated with the emotional distractors. After describing the role of valence, we will move our focus towards the properties of the cognitive task. Using the same distractors on two different tasks, we aim to outline whether the type of task can affect the way emotional distractors influence its completion; moreover, carefully controlling the associated cognitive demands, we aim to establish whether distractors can have a dissimilar influence on different cognitive loads within the same task.
- Define the role of different types of emotional distractors. Once the properties of one type of distractor on the completion of

a task are assessed, the following analysis would focus on the direct comparison of the effects that two different types of emotional stimuli can have on the performance of a cognitive task. This will be evaluated through a careful and meticulous manipulation of the emotional properties of both types of stimuli, matching the respective properties so that any effect highlighted can be ascribed solely to the type of stimulus and its valence levels.

- Define the relevance of emotional salience in the context of emotional distraction. Most of the past research on the topic preferred to use emotionally irrelevant tasks to assess the properties of emotional distractors; others instead used emotionally relevant tasks (for example, the emotional Stroop task). We aimed to compare directly how the same emotional distractors can affect the performance of an emotionally irrelevant and an emotionally salient cognitive task, and whether two different types of distractors can lead to different effects according to the type of task employed. Moreover, within the emotionally relevant task, we aimed to define whether emotional congruency between the target and distracting stimuli could lead to different effects in task performance (i.e. whether valence congruence provides an advantage in the evaluation of targets' valence in comparison to a respective incongruence).
- Define the mnemonic consistency of the task-irrelevant elements. We propose to study whether the valence of the emotional distractors influences the mnemonic recall of the distracting stimuli and if the different types of distractors we will directly contrast would exhibit different rates of mnemonic sedimentation.
- Within all the studies mentioned, we aim to assess whether personality traits relevant to the processing of emotional stimuli (BIS/BAS dominance, trait impulsivity and trait anxiety) can be

used as a measure to assess task performance or have an effect on the responses provided to a task in the presence of specific valent distractors.

The framework outlined here is absent in the current literature. The unicity and relevance of the work proposed lies not only in the methodological approach toward the study of emotional distraction, which can in principle help to unveil the neural and behavioural mechanisms of physiological interaction between emotion and cognition dimensions through the analysis of task performance parameters (RTs and accuracy rates) and the associated brain activity. In addition, the definition of a role for emotional distractors can potentially be exploited in the treatment of emotion- and attention-related psychopathologies (ADHD, PTSD, etc.). For example, if emotional distractors are found to enhance attention towards an ongoing task, they can be used to sustain attention in ADHD patients.

In order to test the illustrated hypotheses, we designed a battery of five experiments, the first of which included electrophysiological data collection (EEG) along with behavioural measures, while the following four were intended as purely behavioural ones. The aim of each experiment was the following:

- Study 1: define the role of valence through a numerical magnitude comparison task interspersed with emotional distractors. We selected positive and negative emotional pictures from the IAPS database (Lang, Bradley & Cuthbert, 2008) as distractors.
- Study 2: define the role of task cognitive load through a Sternberg delayed response task. We used alphabetical characters as memoranda, with two levels of cognitive load (3 and 6 elements to hold in memory). The emotional distractors used were the same as in Study 1.

- Study 3: define the role of the type of emotional distractors through a numerical magnitude comparison task interspersed with emotional distractors. We selected positive and negative emotional pictures from the NAPS database (Marchewka, Żurawski, Jednoróg & Grabowska, 2014) and positive and negative words from the Warriner's database (Warriner, Kuperman & Brysbaert, 2013).
- Study 4: define the role of task type and its emotional connotations through a valence judgement task influenced by emotional distractors. The distractors used (emotional pictures and words) were the same as in Study 3.
- Study 5: define the role of emotional congruency within an emotionally salient cognitive task through a valence judgement task influenced by emotional distractors. The distractors used (emotional pictures and words) were the same as in Study 4.

The following chapters will illustrate in detail the five experiments performed. Each one will be analysed separately; results will be discussed in light of the current literature and in terms of the novelty each of them brings to the current framework of research in the field. A final chapter with an overall discussion of the full experimental sessions will follow.

4. The effects of positive and negative emotional pictures on task performance: an EEG study.

4.1. Abstract.

Current research on emotional distraction has been unable to draw unequivocal conclusions over the role of valence in the interaction between task-irrelevant stimuli and cognitive performance. A stream of literature highlighted similar effects between positive and negative distractors, while another body of studies detected higher detrimental effects for the negative ones. Moreover, there is currently scarce evidence for which neural networks are predominantly involved in the processing of the affective distractors.

This electroencephalography (EEG) study aimed to test how positive Vs negative IAPS pictures can influence the completion of a numerical comparison task on 15 healthy right-handed participants, particularly in light of their behavioural dominance (BIS/BAS). Task reaction times (RTs) and response accuracy provided a quantitative measure of the influence of the distractors on task performance. EEG coherence, a marker of the functional coupling between brain regions, shed light on the cortical areas involved in the processing of the distractors.

Negative distractors generated significantly higher RTs than the positives, while no differences were found for task accuracy on the numerical task nor in the mnemonic recall of the distractors following the numerical task. Coherence scores in response to the distractors were higher in the left, compared to the right, hemisphere. A significant correlation between coherence scores in response to affective stimuli in the frontotemporal areas and

individual scores of BIS/BAS dominance suggested a hemispherical specialization for the processing of positive and negative stimuli in the left and right hemispheres respectively.

Overall, our findings propose a different influence of positive and negative distractors on task performance, whose cortical activity might be influenced, at the individual level, by personality traits of emotional approach-inhibition.

4.2. Introduction.

Task-irrelevant but emotionally salient stimuli have been proved to affect the performance of different kinds of cognitive tasks, in terms of decreased accuracy and increased time required to their completion (Vuilleumier & Driver, 2007; Vuilleumier, Armony, Driver & Dolan, 2001). This influence has been highlighted systematically and consistently, with only very few exceptions that did not detect any difference between emotional and non-emotional distractors in the effects on task performance (see for example Bendall and Thompson, 2015). Whether receiving processing prioritization or driving a share of attentional resources from task completion to affective processing, emotional distractors play a pivotal role in the interplay between cognition and emotion (Pessoa, 2005).

However, despite the consistent results obtained at a quantitative level, past research has not been able to draw unequivocal qualitative conclusions on this influence. That is, once established an effect of emotional stimuli on task performance, the conclusions over the similarities or differences between positive and negative stimuli are not consistent. In fact, it is still debated what the effects of valence are. According to a body of studies, both positive and negative distractors would bring in the same –detrimental- effects on task performance (Aquino & Arnell, 2007; Schulte

Holthausen, Regenbogen, Turetsky, Schneider & Habel, 2016). Another stream of literature has instead pointed out significant differences between the two (Balconi & Ferrari, 2012; Buchner, Rothermund, Wentura & Mehl, 2004; Hodsoll, Viding & Lavie, 2011; Thomas & Hasher, 2006). These last works, in particular, highlighted how the detrimental effects of negative distractors on task performance were significantly greater compared to the positive ones, in terms of increased RTs and decreased accuracy rates.

The effects of emotional distractors on cognitive processing are however not homogeneous. In fact, it has been demonstrated how domain-congruent distractors produce the highest interference with task-relevant stimuli (Logie, Zucco & Baddeley, 1990). When the modalities differ, for example using auditory distractors in conjunction with a visual task, these disruptive effects are significantly reduced. For this reason, different typologies of emotional distractors have been used in conjunction with an ongoing task: from olfactory (Danuser, Moser, Vitale-Sethre, Hirsig & Krueger, 2003; Ho & Spence, 2005) to auditory (Bonin & Smilek, 2016; Möller, Mayr & Buchner, 2015) or tactile (Frings, Amendt & Spence, 2011; Wesslein, Spence & Frings, 2014). The visual stimuli, however, form undoubtedly the widest category of emotional stimuli used in neurophysiological research, as witnessed by the impressive amount of catalogued stimuli employed in the last decades.

With regard to the brain activity generated by emotionally salient stimuli, what reaches consensus across the almost totality of the studies in the field is the prominence of the frontal and prefrontal cortices in their processing (Gasquoine, 2013; Rudebeck, Bannerman & Rushworth, 2008; Szily & Keri, 2008). Whether relying on the valence hypothesis or the RST to explain the pattern

of lateralization of the activity, these associative areas appear to play a pivotal role in the processing of emotional stimuli. However, most of the previous neuroimaging studies focused on the explicit processing of these stimuli (i.e., recording the brain activity during the passive view of IAPS pictures) (Aydin, Demirtaş, Ateş & Tunga, 2016; Güntekin, Femir, Gölbaşı, Tülay & Başar, 2017; Orgo, Bachmann, Lass & Hinrikus, 2015; Valenza et al., 2015). Scarcer is instead the evidence on the neural networks involved in the processing of affective distractors. The prominence of the role of the frontal cortices does not imply the inactivity of other regions of the brain: response to affective stimuli is a complex process that involves different regions, at cortical (parietal areas, see Davidson & Henriques, 2000; Smith et al., 1987) and subcortical (as the amygdala and the other regions of the limbic system previously described) level. Moreover, depending on the type of stimulation, other areas can be involved: for example, the occipital cortical areas in case of visual stimuli or the piriform cortex in the presence of olfactory stimuli. However, the frontal areas, as associative areas responsible for high-order processes and anatomically connected to several subcortical structures, show consistent and prominent activation in response to emotional stimuli. The position on the cortex allows the study of this area with all the available neuroimaging techniques (unlike the subcortical regions, which cannot be studied with EEG, for example) and the activity in the two hemispheres of the brain is dependent on the valence of the stimulus presented. For these reasons, past research elected this area as one of the most studied at brain level in conjunction with emotional stimuli.

The brain areas active in emotional processing are, in principle, different from the ones deputed to the processing of numbers, which in turn implicate predominantly the intraparietal sulcus (IPS)

(Dastjerdi, Ozker, Foster, Rangarajan & Parvizi, 2013; Pinel, Dehaene, Rivière & LeBihan, 2001). The area is connected with different aspects of numerical processing. These range from numbers representation, even in different forms like Arab digits or number of dots to more or less complex arithmetical operations, basic like single-digit additions and subtractions to more difficult calculations like the conversion from fractions to decimals (Bulthe, De Smedt & De Beeck, 2015; Cappelletti, Muggleton & Walsh, 2009; Schmithorst & Brown, 2004). Other works associated a poor development of this area with dyscalculia, the inability to process numbers and mathematical operations correctly, highlighting again the importance of the IPS in the numbers-processing domain (Molko et al., 2003). Due to this difference, the combination of a numerical task and emotionally salient pictures would be optimal to study, at the cortical level, the activity generated by emotional distractors.

Therefore, using a numerical comparison task interspersed with emotionally salient distractors retrieved from the IAPS database, we aimed to define whether the valence of the distractors would have similar or different effects on task performance. This was investigated at both behavioural level, through the analysis of task RTs and accuracy, and at the brain level, through the study of the cortical activity, via EEG, elicited by the emotional distractors. Moreover, through self-reported measures of behavioural activation/inhibition dominance, we aimed to link the individual personality traits to the behavioural and electrophysiological responses to the emotional distractors.

We hypothesised, at the brain level, a lateralization in the activity generated by the emotional distractors that would follow the same pattern detected when the stimuli are explicitly attended. At the behavioural level, we expected to find a different behaviour of

positive and negative emotional distractors, possibly linked to the behavioural dominance of the participants: higher BAS dominance would be associated with increased facilitation in the processing of positive distractors; therefore, they would produce a weaker interference with the ongoing task. Eventually, we predict that performance in the mnemonic recalling task would provide evidence that, despite being task-irrelevant, the inherent emotional salience of the distractors would facilitate the sedimentation of the stimuli in the memory of the participants.

4.3. Materials and methods.

4.3.1. Participants.

Fifteen right-handed young adults (age: 23.9 ± 2.1 years; range: 21-28), eight of them females, voluntarily agreed to take part in the study. Their laterality index was established using the Edinburgh handedness inventory (Oldfield, 1971): the mean laterality index was 96.0 ± 7.4; ranging between +80 and +100. The study received approval from the local Ethics Committee and, in accordance with the declaration of Helsinki, each participant gave informed written consent to participate before the beginning of the experiment. They received an inconvenience allowance at the end of the session.

4.3.2. Task and procedure.

At the beginning of the experimental session, participants completed the Carver-White questionnaire (Carver & White, 1994) to establish the degree of dominance for the Behavioural Activation/Inhibition Systems.

Immediately after, they completed a numerical magnitude comparison task interspersed with emotional distractors, while brain activity was being recorded via EEG. As illustrated in Fig. 7, each trial started with a fixation cross displayed for 1000ms; then a first digit appeared on the screen for 500ms followed by a distractor window for 1500ms; eventually, a second digit appeared for 500ms. Trials ended with an inter-trial interval of variable duration between 2000 and 4000ms.

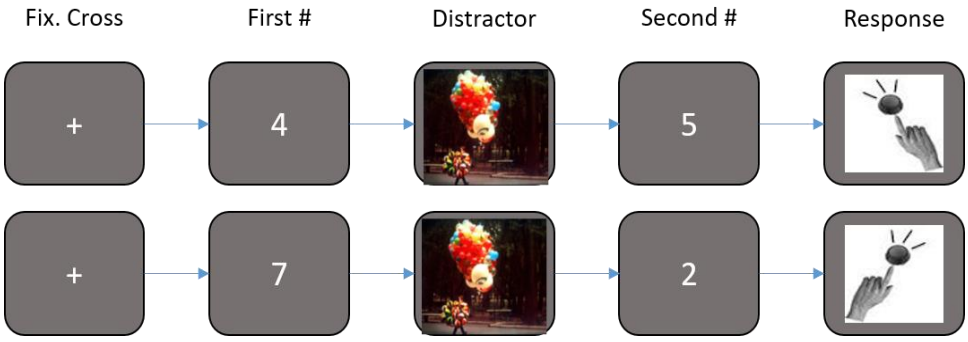


Fig. 7 – Experiment timeline (a trial is displayed in each row).

Participants were instructed to provide a response by pressing a key on a Cedrus RB-830 response box (Cedrus, San Pedro, CA). In particular, if the second digit was bigger than the first (as in the first example displayed in the picture, 4<5), they were asked to press a key with the right index finger; if the first number was bigger, they would have pressed a key with the left index finger. The onset of the second number on the pc screen marked the beginning of the time segment used to calculate RTs. Each participant completed three blocks of trials; within each block, responses with left and right hands were counterbalanced, as well

as the content of the distractor window. The full task contained 105 trials. Before the actual start of the experiment, participants completed a short (5 trials) practice block to get familiar with the structure of the trials, the pace of the presentation and the keys to be pressed to provide their responses.

At the end of the three blocks, participants viewed a set of 20 emotional pictures, evenly split into positive and negative. They were asked to rate the pleasantness of each stimulus on a 9-point scale; subsequently, they stated whether the picture had been presented during the RT task or it was being displayed for the first time during the experimental session. Pictures were displayed for 3000ms and were preceded by a fixation cross, displayed for 2000ms, appearing on the screen after the responses to the antecedent trial were provided. Participants were unaware of the presence of this last block although were told, during the experiment, not to focus only on the cognitive task but to pay attention to the distractors too.

4.3.3. Stimuli used.

For the RT task, we employed single-digit numbers between 2 and 8. Participants were not aware of the absence of digits 1 and 9, which were removed to limit the anticipation of responses from the first digit window.

The emotional stimuli employed have been retrieved from the International Affective Picture System (IAPS; (Lang, Bradley & Cuthbert, 2008). It contains over 1000 emotional pictures portraying a wide variety of subjects (landscapes, people, objects, animals, etc.), eliciting a varied range of emotions. Each picture has been classified according to hundreds of ratings on two nine-point scales for valence and arousal dimensions. For valence, stimuli are considered negative when rated between 1 and 3,

neutral between 4 and 6, positive in the 7-9 range; for arousal, the neutral level is generally considered between 1 and 3 (see for example Dolcos, LaBar & Cabeza, 2004), rather than at the middle of the scale. Pictures from the IAPS database have been often used as distracting elements in conjunction with a cognitive task (Bekhtereva, Craddock & Müller, 2015; Casarotto, Ricciardi, Romani, Dalli & Pietrini, 2012; Müller & Gundlach, 2017). However, the lack of control on several variables (as pictures content, arousal neutrality, etc.) have led to critical discrepancies in the study of emotional distraction.

For this reason, we selected our stimuli on the bases of their normative ratings for both valence and arousal. We employed only pictures with arousal normative ratings between 1 and 3. The valence level for the positive pictures was between 7 and 9; for the negative ones between 1 and 3.

In the RT task, we used 35 positive and 35 negative distractors; to these, 35 scrambled pictures were added, to prevent habituation effects to the valent distractors (an example is shown in Fig. 8). The scrambling effect was created using the software Gimp 2.8, through an in-house algorithm to obtain the effect illustrated.



Fig. 8 - An example of a scrambled picture used (left), compared to the original one (right).

Within each valence level of the emotional distractors, we balanced the pictures in terms of complexity (low or high) and content (people, objects, animals, human faces and natural scenes) of the scene depicted. Along with the valence, these parameters were also balanced within each of the three experimental blocks, as well as for the hand of response. With regard to complexity of the composition, the IAPS database does not provide a specific measure for picture complexity (as, for example, the NAPS database does). In this case, complexity was initially determined via visual inspection of the distractors: pictures with clear front-background composition were classified as low complex; pictures depicting more intricate scenes (for example, a group of people or a landscape) were classified as high complex. Subsequently, we used a MATLAB customized script to count the edges in each picture as an objective measure of its complexity, to confirm the results of the visual inspection. All the pictures previously included in the low complexity group had a number of edges inferior to all the pictures classified as high complex.

In the memory task that followed the RT task, we selected 10 positive and 10 negative pictures, 20% of which have been already presented during the RT task and the remaining 80% were new to the participants. The new pictures were selected on the same criteria for valence and arousal; the previously seen pictures were instead selected randomly within the pool of stimuli used in the RT task.

4.3.4. EEG recordings and behavioural measures.

RTs during the three blocks of the RT task have been calculated as the time lag between the onset of the second number window on the screen and the key press to respond the trial. The accuracy rates of both the RT task and the memory task have been

calculated for each participant, along with the subjective valence ratings for the pictures presented in the memory task.

Continuous EEG signal was recorded using a Sensorium 124-channel system, at a sampling frequency of 1000Hz and band-pass filtered between 1 and 100Hz, using a Notch filter at 50Hz to reject AC noise. All the data have been referenced to an external electrode placed on the left mastoid of the participants (i.e. behind the left ear). Data were pre-processed using BESA software (MEGIS Software GmbH, Gräfelfing, Germany) and Matlab EEGLAB toolbox (Delorme & Makeig, 2004).

During the preprocessing, artefacts in the EEG traces, such as muscle contractions, eyes movements and head rotations were corrected exploiting a pattern recognition algorithm integrated within the BESA software, and a second control has been performed in Matlab using the Independent Component Analysis (ICA, Jung et al., 1998). ICA analysis complemented the artefact rejection performed in BESA. In fact, BESA uses an algorithm to detect artefacts in EEG data based on the shape of the artefact itself in the traces: for example, an eye blink has a unique, triangular shape in the EEG trace. BESA is able to determine the artefact using the knowledge of the associated EEG output. Using ICA, instead, the artefacts are determined in terms of independency of the signal in the different channels. Therefore, in this second control, an artefact is marked not for its shape on the trace, but on the grounds of its dependency/independency of the physiological signals and the noisy ones. It is a complementary way to clean the data: although one of the two methods could be sufficient to obtain clean data, the application of both techniques allows the analysis of purer, cleaner signals.

Continuous EEG was then fragmented in 8-seconds blocks (duration of a single trial) starting from the onset of the fixation cross in each trial and removing the last part of the inter-trial

interval to match a common length for all the blocks. Being each segment independent of the others (no overlap among contiguous segments), we obtained 105 segments per participant.

After visual inspection, trials containing an excessive number of artefacts or noise, in which correction resulted inefficient, were excluded from the analysis. We considered for the analysis only the trials in which a correct response was provided. Overall, beyond 93% of the total trials have been kept for each participant, with an average rejection rate of 4.7% of the total trials per participant. Visual inspection was adopted as a further measure to control for the presence of artefacts. In fact, while most of the common artefacts are removed through shape-based algorithms (BESA) or signal-dependency criteria (Matlab EEGLAB), some trials might still result noisy or heavily distorted by the application of the corrections. In this case, visual inspection is the most commonly used –and possibly most efficient- method to control for the quality of the data. While, in fact, the major and most numerous artefacts are efficiently removed using different software, the visual inspection ensures a further, final and decisive check on the data in possession of the experimenter before performing any type of analysis. Trusting exclusively a software to remove all the artefacts is indeed less time consuming and less effortful, but in most cases also less qualitatively valid.

4.3.5. EEG coherence analysis.

We analysed the EEG data by the means of coherence scores. Coherence measures, in the frequency domain, the statistical dependency of two signals; scores span from 0 to 1 (i.e. from 0% to 100%): the higher the score, the higher the correlation between the two signals. With reference to EEG signals, coherence scores represent a measure of functional connectivity between two areas:

if at a given frequency, two electrodes record a highly correlated activity, this is interpreted as an increased functional connectivity between the cortical areas recorded by the two electrodes.

The advantages in running this type of analysis, in comparison to other, more traditional methods of brain activity analysis, are multiple. In the first instance, to our knowledge, this analysis has never been performed in the domain of emotional distraction, in order to underpin the neural bases of the processing of task-irrelevant affective stimuli. Secondly, unlike ERP analysis, functional connectivity allows the study of the effects of these distractors on brain activity not at a localised level, considering the response of a single cluster of cortical neurons recorded by a single electrode. Rather, it helps determining the possible long-range networks involved in the processing of these stimuli, allowing a better understanding of how the brain is wired and organizes itself to respond to affectively salient but irrelevant stimuli.

This analysis, when compared to others performed in the frequency domain (for example, PSD), results more complete since it provides information not only on the frequency bands at which the most relevant activity is taking place, but also to the level of synchronization across different areas. Again, this last piece of information is essential to understand not only how the brain works (i.e. the electrophysiological aspect) but also how the brain is wired (i.e. the neuroanatomical component), according to the well-established principle that, in the brain, "what fires together, wires together" (as defined by Donald Hebb in 1949).

Therefore, the motivation behind the choice of functional connectivity analysis to investigate our EEG data is threefold. It is in the first instance a strong element of novelty, being applied to this type of data for the first time. It is extremely helpful for the completeness of information provided, compared to other, traditional EEG data analyses in the time or frequency domain.

Finally, it adheres to the latest requirements in the study of emotional distraction: as previously mentioned by Okon-Singer et al (2015) and Pessoa (2008), the study of the interaction between emotion and cognition must contemplate a methodological approach that focuses on long-range networks rather than isolated structures, to truly understand the brain mechanisms behind this interplay.

In this study, coherence scores were computed by means of complex demodulation as implemented in BESA: this procedure allows the definition of the amplitude and phase of an oscillation in the neighbourhood of a pre-defined time interval rather than the entire series, a harmonic analysis at a local level. Each EEG trial, lasting 8s, was split into intervals of 25ms; within this block, we extracted the fundamental harmonic of the oscillation, calculated every 2Hz within the Alpha band range (8-12Hz), and a residual component. For the fundamental harmonic, the phase synchronization was calculated within each pair of the electrodes analysed. The procedure was then repeated in the following 25ms interval for all the fundamental harmonics of the frequency band. We selected the Alpha rhythm to calculate coherence scores for its relevance in the activity ongoing at the brain level. Alpha is, in fact, the dominant rhythm in the processing of emotional stimuli, especially across the frontal sites (Weinreich, Stephani & Schubert, 2016). The inverse hyperbolic tangent transformation was then applied to the calculated scores to normalize the results. This standard procedure allowed highlighting the stronger coupling scores while, at the same time, suppressing the lower ones. After the transformation, a baseline correction was applied by dividing the coherence scores obtained in the distractor window by the scores of a 100ms segment in the fixation cross window, selecting a stable interval for the correction (i.e., avoiding spikes of increased coherence or deep depressions led by non-functional

factors). Therefore, each ratio value above the unity represented, within each pair of electrodes, a brain connectivity index higher in the distractor window than the baseline in the fixation cross. In the rest of the chapter, we will refer to this score as "coherence ratio" and this will be the measure of brain connectivity used in the current study.

The procedure illustrated above was not applied to any couple of electrodes among the 124 channels we recorded. In fact, one issue in using coherence analysis is the discrimination between the true functional coupling and other factors, which can increase coherence scores despite being irrelevant at the functional level (Nolte et al., 2004). One of these factors is volume conduction, that is, different EEG channels record the activity of the same cluster of neurons, due to the distortions the signal suffers travelling from the cortical areas to the recording electrode. This is particularly true for neighbour sensors, especially in high-density montages (60+ channels), where the inter-channel distance is extremely low (but necessary to obtain a higher spatial resolution). For this reason, we conducted the analysis on 12 of the original channels. We split them into two symmetrical Regions of Interest (ROIs) which comprised of prefrontal, frontal and temporal sites. Within each ROI we calculated inter-regional coherence scores for all the pairs of electrodes belonging to it (Fig. 9). Channels selected for the analysis were: FP1, AF3, F3, F7, T7, TP7 in the left ROI; FP2, AF4, F4, F8, T8, TP8 in the right ROI. The channels belonging to the two ROIs have been selected on the grounds of functional interest in the emotional processing, encompassing the prefrontal, frontal and temporal regions of the cortex (Gaeta, Susac, Supek, Babiloni & Vecchiato, 2015).

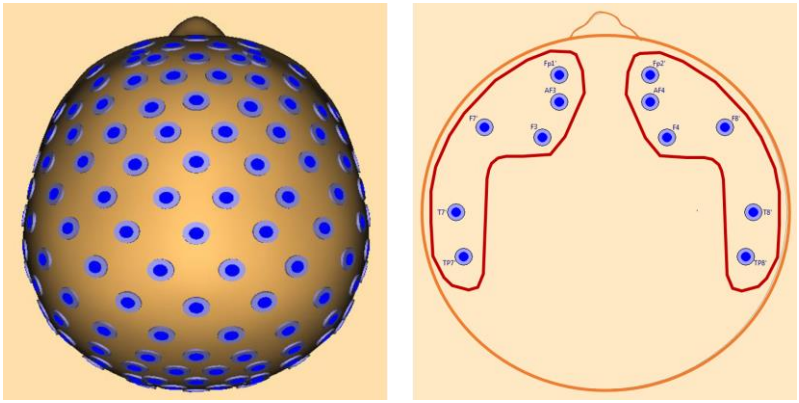


Fig. 9 - The original EEG montage used (124 channels) for the recordings (left) and the reduced montage (12 channels) used for the functional connectivity analysis. The relative distance across the electrodes is not to scale, but used for illustration purposes only.

Within each ROI, we calculated the coherence scores between each pair of electrodes in the time interval corresponding to the presentation of the emotional distractor, at the Alpha band rhythm. After applying the baseline correction illustrated, we averaged the coherence ratio scores for each ROI, in the different conditions of valence, that is, for the positive and the negative distractors. In this way, we obtained, for each participant, and within each hemisphere, one value for the average of the coherence scores in response to positive distractors and one in response to the negative ones. The ultimate goal of the procedure is to analyse the hemispherical differences in the processing of the emotional distractors from a regional perspective rather than taking into account the single connections. This process allows to highlight the involvement of different cortical areas, and in particular long-range networks, that have been found involved in the processing of emotional stimuli (Güntekin, Femir, Gölbaşı, Tülay & Başar, 2017). In the work from Güntekin and colleagues, however, the participants have actively attended the emotional

stimuli: here we aim to define the role of each hemisphere in the processing of emotional distractors which are not relevant for the completion of the task. For these reasons, only regional average coherence scores will be reported, rather than focusing on the scores of the single connections.

4.3.6. Statistical analysis.

For the Carver-White questionnaire, overall BIS/BAS dominance was established by the means of t-tests on the average scores for the two Activation and Inhibition scales. We did not use raw overall scores due to the different number of items that each scale presents within the questionnaire.

With regard to the behavioural data, the RTs for the cognitive task were analysed by means of 2 x 2 ANOVA (Valence: Negative Vs Positive; Hand: Left Vs Right). The same statistical test structure has been used to analyse task accuracy.

For the memory task, both the valence ratings and the memory performance were analysed by means of paired t-test for the two valence levels (Negative Vs Positive).

The coherence data were analysed by means of 2 x 2 ANOVA (Hemisphere: Left Vs Right; Valence: Negative Vs Positive) in the Alpha band. We averaged the functional connectivity scores calculated in the distractor window for all the pairs of electrodes located in each ROI to obtain the mean value of connectivity within each hemisphere.

Brain-behavioural correlations were calculated as Pearson's Correlation Coefficient between the coherence ratio scores of the electrodes pairs in each ROI, during the Distractor window, and the average scores for the BIS/BAS scales (Balconi, Falbo & Brambilla, 2009).

For all the tests, the statistical threshold was set at $p < 0.05$; we applied Bonferroni corrections for multiple comparisons where appropriate. Throughout the Results section, mean scores ± SE are reported.

4.4. Results.

4.4.1. Behavioural systems dominance.

We found a significant difference in the behavioural dominance of the participants from the average scores on the BIS and BAS scales ($t=2.59$, $p<0.03$). Scores for the BAS scale were significantly higher compared to the BIS scores ($M_{BAS}=4.32\pm0.33$; $M_{BIS}=3.70\pm0.76$).

4.4.2. Behavioural measures for the RT task.

For the accuracy scores, no significant effects have been found ($p>0.1$). Task accuracy was, overall, equal to 97.4±2.9%. No participant reached the ceiling of 100% accuracy.

For the RTs, there was a significant main effect of Hand ($F(1.14)=6.52$, $p<0.03$, partial $\eta^2=0.21$). RTs for the responses with the right hand were significantly faster compared to the left hand ($M_R=615\pm45$ms; $M_L=647\pm47$ms).

There was also a significant effect of Valence ($F(1.14)=4.73$, $p<0.05$, partial $\eta^2=0.22$). RTs for the trials containing a negative distractor were significantly higher than for the ones containing a positive distractor ($M_N=641\pm46$ms; $M_P=622\pm47$ms).

The interaction effect between the two main factors did not reach statistical significance ($p>0.25$, $F<1.3$).

In a second stage, we repeated the analysis on RTs and included the response time to the scrambled pictures. We found a significant effect for the hand factor ($F(1,14)= 9.16$, $p<0.01$,

partial η^2=0.40). RTs for the responses with the right hand were significantly faster compared to the left hand (M_R=612±44ms; M_L=652±44ms). The remaining effects were not significant (p>0.1, F<3).

In terms of valence, the mean RTs for the scrambled pictures (M_S=633±39ms) were intermediate between the positive and the negative RTs (M_N=641±46ms; M_P=622±47ms). In the pairwise comparison between the scrambled distractors RTs and both the positive and negative distractors RTs, both contrasts resulted non-significant (p>0.7).

We also repeated the same analysis for the accuracy scores, including once again the scrambled distractors as a third level in the Valence factor. No effect reached the threshold of significance (p>0.2).

4.4.3. Behavioural measures for the memory task and the valence rating task.

For the memory task, accuracy while stating whether the picture displayed has been previously seen or not was not significantly different for positive and negative stimuli (p>0.05). Overall task accuracy was equal to 87.8±8.0%.

For the rating task, we found a significant difference in the ratings to positive and negative stimuli (t=12.93, p<0.001). Positive pictures have been rated significantly higher than the negative ones (M_P=7.03±0.50; M_N=3.83±0.60).

4.4.4. Functional connectivity analysis: coherence scores.

For the coherence ratio scores, there was a significant main effect of Hemisphere (F(1,14)= 13.76, p<0.005, partial η^2=0.31).

Coherence ratio scores during the processing of the emotional distractors were significantly higher on the left, compared to the right, hemisphere (M_L=3.75±0.41; M_R=2.34±0.14). The remaining effects did not reach statistical significance ($p>0.3$, $F<1$).

Table 1 reports, for each connection, the coherence ratio score averaged across all the participants.

Left ROI			**Right ROI**		
	Positive	Negative		Positive	Negative
FP1-AF3	1.59	1.50	FP2-AF4	2.23	1.88
FP1-F7	1.95	3.41	FP2-F8	2.00	2.33
FP1-F3	3.49	3.21	FP2-F4	2.12	2.34
FP1-T7	2.68	3.04	FP2-T8	2.94	3.22
FP1-TP7	3.76	3.16	FP2-TP8	2.85	2.52
AF3-F7	1.53	4.10	AF4-F8	1.47	1.87
AF3-F3	9.94	6.37	AF4-F4	1.48	2.27
AF3-T7	2.40	2.81	AF4-T8	2.72	2.38
AF3-TP7	3.16	3.28	AF4-TP8	2.36	2.72
F7-F3	15.26	10.53	F8-F4	1.57	2.08
F7-T7	1.92	2.57	F8-T8	2.26	2.42
F7-TP7	2.54	3.51	F8-TP8	3.04	2.85
F3-T7	2.33	2.70	F4-T8	2.23	1.82
F3-TP7	2.85	3.25	F4-TP8	2.82	3.66
T7-TP7	2.03	1.63	T8-TP8	1.95	1.82

Table 1 – Coherence ratio scores calculated in each connection of the two ROI during the processing of the affective distractors.

4.4.5. Brain-behavioural correlations.

In the left hemisphere, there was a significant inverse correlation between the average BAS scores and the coherence ratio scores in response to positive distractors in the F7-T7 connection (PCC=-0.52; $p<0.05$) (Fig. 10).

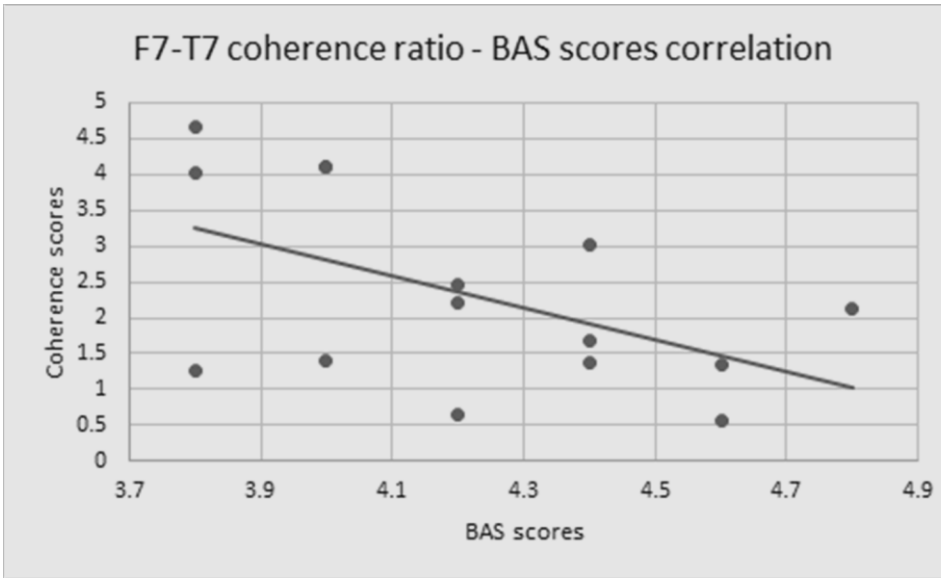


Fig. 10 – Brain-Behavioural correlation calculated in the left hemisphere. Y-axis: coherence ratio scores calculated during the presentation of positive pictures; X-axis: Self-reported measures of BAS dominance. The analysis refers to the F7-T7 connection.

Participants registering higher self-reported measures of BAS dominance displayed lower coherence ratio scores for the F7-T7 connection, in the Alpha band, while positive emotional pictures appeared on screen as distractors.

In the right hemisphere, there was a significant inverse correlation between the average BIS scores and the coherence ratio scores in response to negative distractors in the F8-T8 connection (PCC=-0.54; $p<0.04$) (Fig. 11).

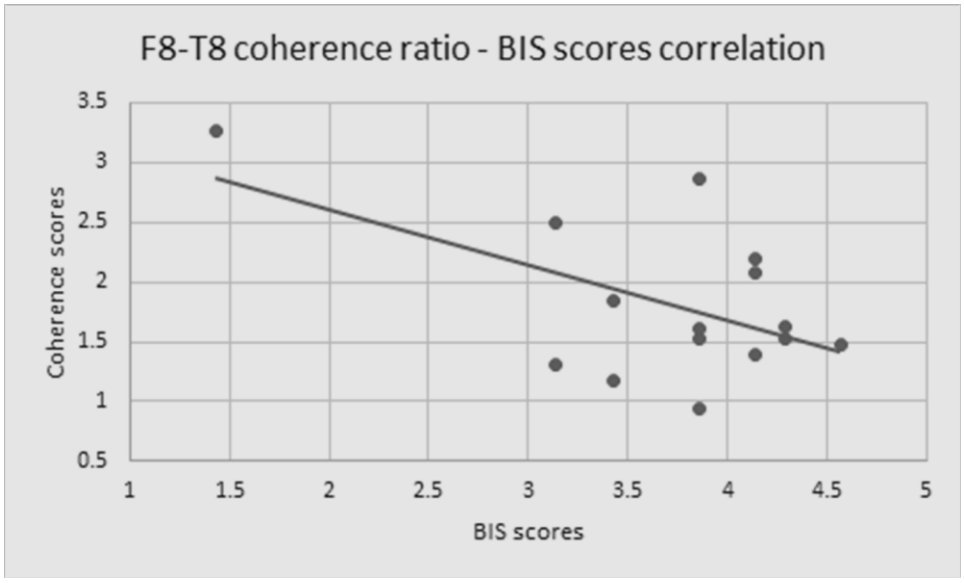


Fig. 11 – Brain-Behavioural correlation calculated in the right hemisphere. Y-axis: coherence ratio scores calculated during the presentation of negative pictures; X-axis: Self-reported measures of BIS dominance. The analysis refers to the F8-T8 connection.

Participants registering higher self-reported measures of BIS dominance displayed lower coherence ratio scores for the F8-T8 connection, in the Alpha band, while negative emotional pictures appeared on screen as distractors.

To control for the effects that a single outlier can have on the correlation analysis, the same test was repeated removing the participant with the lowest BIS score. For the repeated analyses, Bonferroni correction for multiple comparisons has been applied. After the repetition, the correlation did not reach the significance ($p>0.05$).

Fig. 12 illustrates, at scalp level, the position of the connections for which the correlation analysis between BIS/BAS scores and coherence ratio scores of the connection analysed resulted significant (in particular, the connections F7-T7 and F8-T8).

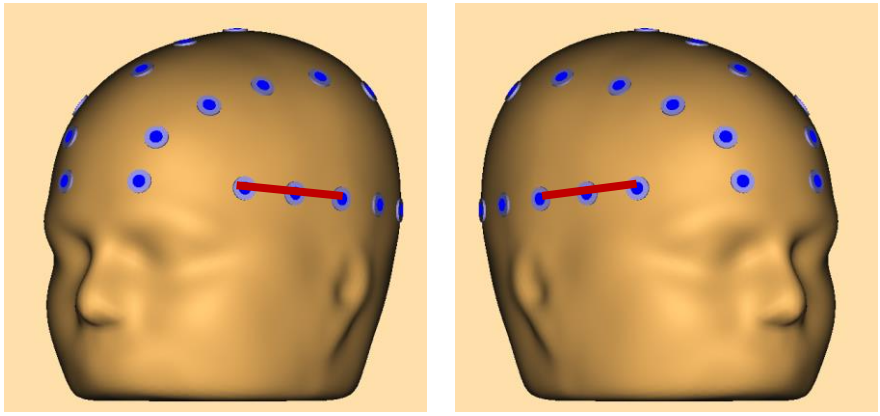


Fig.12 – 3D representation of the significant connections in the Brain-Behavioural correlations at the electrodes sites. In the picture on the left is displayed the frontotemporal network in the left hemisphere comprising the connection F7-T7. In the picture on the right is displayed the frontotemporal network in the right hemisphere comprising the connections F8-T8.

4.5. Discussion.

In the present study, we examined the effects of positive and negative emotional distractors on the completion of a numerical magnitude comparison task.

The analysis of behavioural measures pointed out a significant advantage in task performance brought on by positive distractors, in terms of faster responses without any significant difference in accuracy rates. Moreover, responses with the dominant hand have been found to be significantly faster than the non-dominant.

At the brain level, we highlighted a significantly higher activity, in the Alpha band, for a left-hemisphere network comprising the prefrontal, frontal and temporal areas of the cortex, in comparison to the homologous in the right hemisphere, independent of the valence of the distractors.

However, when correlating the activity between the nodes within each ROI and the scores of self-reported measures of BIS-BAS dominance, we were able to identify two symmetrical frontotemporal networks, in the two ROIs, possibly involved in the processing of positive and negative distractors respectively. However, due to the lack of significance for the correlation in the right ROI after one outlier was removed, we will comment only on the left frontotemporal network, as the result in the right ROI cannot be considered robust enough.

4.5.1. Task performance: effects of positive and negative distractors at the behavioural level.

The interaction between emotional distractors and cognitive task completion is represented, at the behavioural level, by performance parameters of RTs and accuracy rates. Our results are in agreement with the stream of research pointing out a different effect of positive and negative distractors on task completion. We successfully replicated the results of several studies suggesting how positive distractors, compared to negative ones, would bring to a significant reduction in task response time (see for example Buchner, Rothermund, Wentura & Mehl, 2004; Hodsoll, Viding & Lavie, 2011; Pereira et al., 2004; Wiswede, Münte, Goschke & Rüsseler, 2009). No significant drop in the accuracy rates compensated this reduction; therefore, a speed-accuracy trade-off was not present. One possible explanation for this discrepancy between positive and negative distractors is the higher attentional demands required by the processing of negative

stimuli (Compton, 2000). Being considered essential for survival, not only would they receive prioritized processing, but also would require sustained attention while elaborated, amplifying the difficulty to switch back from the processing of the distractor to the completion of the task and consequently increasing the time to respond to the task itself.

Statistical analysis also highlighted a significant decrease in RTs when the response is provided with the dominant, compared to the non-dominant hand. Robust evidence from previous neuroimaging and lesion studies supports the idea of a stronger activity of the left hemisphere, compared to the right, during the completion of this type of numerical comparison task (Andres, Seron & Olivier, 2005; Ansari, 2007; Cappelletti, Barth, Fregni, Spelke & Pascual-Leone, 2007; Colvin, Funnell & Gazzaniga, 2005; Dehaene, 1992; Dehaene & Cohen, 1995; Notebaert & Reynvoet, 2009). This stronger involvement can explain a facilitation of the response provided with the right hand, whose activity is also controlled by the left hemisphere.

The second analysis run on the RTs, which included the scrambled distractors as a third level in the Valence factor of the ANOVA test, pointed out how this improvement in performance from positive distractors is not only manifested in comparison to a negative, homogeneous condition, but also with respect to a non-emotional condition -although not significantly in this last case. In fact, despite the lack of significance of the direct comparison between the RTs in the presence of positive and non-emotional distractors, the former condition determined a decrease in RTs compared to the latter. Conversely, the presence of negative distractors determined an increase (although, again, non-significant) in the mean time needed to complete the task, in comparison to a non-emotional condition. As previously illustrated, past research almost exclusively contrasted the effects of a single level of valence (i.e.

either positive or negative distractors) against a neutral baseline (see for example Bendall & Thompson, 2015). Through this second analysis we have been able not only to draw conclusions over the effects of positive Vs negative distractors, through a direct comparison of the two emotional conditions, but also referencing each condition to a non-emotional baseline. Our results did not show, however, significant differences between this non-emotional condition and either positive or negative distractors, in terms of task performance. This result, apparently in contrast with what found in past research, can be explained in terms of the types of stimuli employed in the neutral baseline. While past studies almost exclusively employed neutral pictures, we chose to use scrambled pictures in order to prevent any further processing of the stimuli at a cognitive level (e.g. the interpretation of the scene displayed). Moreover, most of the results from past studies present in the literature are affected by the variable of arousal, which has been often not controlled: in fact, while neutral pictures tend to have, for the vast majority, low arousal normative ratings, the affective stimuli employed have higher arousal ratings for the most part. This, particularly when dealing with negative stimuli, can induce significantly higher RTs in the affective, compared to the neutral, condition.

Despite the lack of statistical significance, the relevant result of this second analysis is the definition of a relationship between the two affective conditions and, additionally, between each of the two and a non-emotional baseline. We showed how the presence of positive distractors could lead to a reduction in task RTs, therefore to an improvement in task performance, in comparison not only with negative distractors, but also with a non-emotional baseline. In parallel, the presence of negative distractors could lead to a deterioration in task performance, in terms of higher RTs, not only in comparison to homologous, positive distractors, but also to a

non-emotional, control baseline. Under this point of view, it would be acceptable to describe these effects as improvement in task performance due to the presence of positive distractors and, at the same time, deterioration in task performance due to the presence of negative task-irrelevant stimuli.

Moreover, the high BAS dominance of the participants could have also influenced the speed of response with the right hand. In fact, highly consistent right-handedness has been associated with a higher sensibility to BAS activation (Hardie & Wright, 2014). Testing a large sample of participants (>600), the authors established a direct association for consistent left-handedness with BIS dominance and for consistent right-handedness with BAS dominance. In other words, consistent left-handers tend to show higher BIS dominance and consistent right-handers tend to show higher BAS dominance. Interestingly, this result was assessed using the two questionnaires (Edinburgh Handedness Inventory and Carver-White scales) also employed in the current experiment. They interpreted this result in terms of homogeneity of the hemispheres involved: the left hemisphere controls the right hand and is responsible for the management of the BAS system. For this reason, a general higher engagement of the left, compared to the right hemisphere, in consistent right-handers would express its effects in terms of both behavioural dominance and hand preference. In relation to our own study, the BAS is activated by the presence of the positive distractors and, therefore, could drive an advantage in task response with the dominant hand of our participants, being all of them consistent right-handers. However, the present result must be considered with caution and further research is needed, especially because, in the current literature, no other similar analysis on emotional distraction has ever been performed. Nonetheless, it must be noticed how the participants were required to complete the task using the two hands

simultaneously within the same block. In the future, a task that separates the performance with the left and right hand in different blocks would be beneficial to clarify the role of consistent handedness in the field of emotional distraction.

4.5.2. Memory task performance: the relevance of emotionally salient distractors.

For the memory task, we found no significant differences across positive and negative distractors in terms of ability in the mnemonic recall of the distractors. This result is in agreement with other studies underlining how arousal, and not valence, is a modulator of mnemonic sedimentation (cf. Dolcos, Labar & Cabeza, 2004). In fact, low-arousing stimuli, compared to high-arousing ones, are weakly memorised but, often, no differences have been highlighted across the different valence levels neither for low- nor for high-arousing stimuli. Secondly, and more importantly, the distractors do not appear to play a marginal role in working memory. The high accuracy rate in the memory task, in conjunction with the incidental learning paradigm adopted, strongly supports the idea that the emotional distractors actually drive a share of attention from the cognitive to the emotional elements (Dolcos, Iordan & Dolcos, 2011; Pessoa, McKenna, Gutierrez & Ungerleider, 2002).

4.5.3. Functional connectivity analysis: a stronger involvement of the left hemisphere.

The cortical activity in response to the distractors appears to follow a precise pattern of brain lateralization, which fits Gray's RST better than the valence hypothesis, especially in the context of frontal asymmetries (Davidson, 1992, 1998). In fact, according to the latter hypothesis, we would have expected a stronger activity

(and therefore higher coherence scores) for the positive distractors in the left hemisphere and for the negative ones in the right hemisphere. We found instead no Distractor x Hemisphere interaction, but a stronger involvement of the left hemisphere in the processing of emotional stimuli, which matches the dominant behavioural system of the participants, under the hypothesis that the left hemisphere is controlled by the BAS. From this higher involvement follows a significant decrease in RTs for the trials containing positive distractors, a facilitation in task completion compared to the opposite valence level. This result is in agreement with other studies which previously found an increased activity in the left hemisphere, compared to the right, in participants displaying a BAS dominance in approach-driven contexts, like the perception of positive emotional stimuli (Amodio, Maste, Yee & Taylor, 2008; De Pascalis, Varriale & D'Antuono, 2010).

Another interpretation of the previous finding can involve the consideration of the BIS not related to the reception of negative stimuli but as a conflict detection system. The higher activity in the left hemisphere has been robustly connected to the BAS (Balconi & Cobelli, 2014). On the other hand, an analogue result for the right hemisphere failed to be systematically proved, leaving open the question of whether the area is linked with other processes transcending the pure withdrawal motivation (Coan & Allen, 2004). These studies hypothesized a possible simultaneous presence of different activities ongoing in the right hemisphere in the broader context of emotional withdrawal/inhibition, which can justify the incongruences of the findings regarding this hemisphere. While corroborating the results over the activity of the frontal areas in the left hemisphere, the current study cannot infer anything about the relationship between right frontal cortex and inhibitory processes due to the significant difference between BIS and BAS scores of the participants.

4.5.4. Brain-behavioural correlations: two independent frontal networks for valent distractors.

Behavioural dominance must not be intended as an absolute parameter, but as a scale, like handedness, with different degrees of consistency for the dominant system. The degree of dominance has been associated with the activity of the respective hemispheres controlled by the two behavioural systems: several studies highlighted a tight, stable and reliable link between the two parameters (Balconi, Vanutelli & Grippa, 2017; Barrós-Loscertales et al., 2010; Diego, Field & Hernandez-Reif, 2001). In particular, higher degrees of BAS dominance negatively correlate with higher activity in the left hemisphere, both in resting state condition and during the processing of positive affective stimuli. This pattern has been found true regardless of the level of arousal of the stimuli: in fact, both high- and low-arousing stimuli display the same trend. Moreover, the stimuli used in the work by Balconi and colleagues are retrieved from the same database we used in the current study, allowing a strong comparison between the results obtained.

Our data point in the same direction of these previous findings, particularly concerning the activity in the left hemisphere associated with the degree of BAS dominance. The increasing self-reported scores of BAS dominance described by our participants inversely correlated with coherence ratio scores related to the processing of the positive stimuli. A lower degree of correlation is interpreted as a facilitation, in the proposed network, for the processing the positive distractors.

The fundamental element of novelty generated within our study lies in the replication of the same results present in the literature when however the stimuli are elements of the task. In all the previous studies, the participants were asked to attend the affective stimuli as part of the task (or, sometimes, as the task

itself), while in our case the processing of the stimuli is parallel to an ongoing cognitive task, to which the affective stimuli are irrelevant, distracting elements. However, despite this methodological difference, our results reconcile with what stated by past research on the processing of affective stimuli, that is, the pivotal role played by the activation and inhibition systems in the processing of positive and negative affective stimuli respectively.

The same result, although in a network involving symmetrical nodes, is replicated in the right hemisphere in the inverse correlation between BIS dominance scores and the brain coherence ratio scores in response to the negative distractors. Due to the presence of extreme points (i.e. possible outliers) in the data, although statistically significant, the result must be taken carefully and further analysis is needed in order to replicate and confirm the salience of the proposed network in the processing of emotional distractors.

The illustrated correlation is in agreement with the RST: valence hypothesis, in fact, would have predicted specular effects of the two types of distractors across all the participants, while the behavioural systems theory links these differences to the degree of the individual behavioural dominance (Beraha et al., 2012). Our correlation analysis suggests how the different degree of BAS dominance can modulate the brain response to positive affective distractors.

4.5.5. Lateralization in the emotional processing and influence on task performance.

Participants' BAS dominance and, consequently, the stronger involvement of the left frontotemporal areas, compared to the right, must not mislead, suggesting an inactivity of the right hemisphere. In fact, in the correlation analysis, we examined in each hemisphere the activity of both positive and negative

distractors in relation to the coherence scores, but significant results were obtained exclusively between each hemisphere and the associated valence level. In particular, in the left hemisphere, we found a significant inverse correlation between the self-reported measure of BAS dominance and the activity generated by positive distractors, in a network involving the frontotemporal areas of the hemisphere. This result is in agreement with other studies which suggested a facilitation, in the processing of positively valent stimuli, growing with increased BAS dominance (Gable & Harmon-Jones, 2013). Instead, no significant result has been obtained, within the left hemisphere, for the correlation between BIS scores and coherence ratio scores in response to negative distractors.

This difference in the processing of positive and negative stimuli has not isolated effects, but reverberates on task performance: participants, in fact, benefitted from the presence of positive distractors and provided significantly faster responses to the numerical task compared to the trials in which a negative picture was displayed.

4.5.6. Limitations of the current study and future directions.

The current study provided interesting insights into the study of emotional distraction through the direct comparison of the effects that positive and negative distractors have on the completion of a task. A clear difference was found between the two levels of valence, in terms of both behavioural data and electrophysiological measurements. Positive distractors led to a significant reduction in the time needed to complete the task, without however suffering any decrease in accuracy. At brain level, a higher involvement of the left hemisphere during the processing of the emotional distractors has been detected in a network comprising prefrontal,

frontal and temporal areas, in comparison to the right hemisphere. The correlation analysis between the brain activity in response to emotional stimuli and the valence ratings assigned to them suggested a different hemispherical specialization for the processing of positive and negative distractors. However, the current work utilised a task with a low cognitive load: future research would need to take into account a task with a higher cognitive load, or different levels of it, to assess how positive and negative distractors relate to the increase of task demands.

Moreover, the results highlighted a relevant role of personality traits of BIS/BAS dominance. If individual behavioural dominance contributes to the processing of emotional distractors, then differences in emotion-related personality traits might contribute to explain differences in the performance of the same task when emotional distractors perturb it. For these reasons, the following work will include the analysis of traits like anxiety and impulsivity, cornerstones of the architecture of Gray's behavioural systems. These traits can be expressed via self-reported measures (questionnaires) and the degree of each trait can be put in correlation with task performance (RTs and response accuracy).

5. Emotional distractors influence the performance of a task with different cognitive load levels.

5.1. Abstract.

In the realm of emotional distraction, it is unclear whether distractors would receive prioritized and automatic processing due to their affective salience or if they are elaborated in parallel with cognitive elements, sharing the attentional resources available. A variable often poorly controlled is the difficulty of the tasks employed to study these processes.

The current study aimed to describe how positive Vs negative IAPS pictures affected the completion of a Sternberg delayed response task, where the memoranda -arrays of consonants- were composed of either three or six items. Thirty right-handed young adults completed the aforementioned task, a mnemonic recollection task on the distractors presented and self-reported questionnaires to outline their affective dominance (BIS/BAS).

Behavioural measures of reaction times (RTs) and response accuracy provided quantitative information on the interference of the distractors on task performance. Questionnaires scores were correlated with behavioural data to analyse individual modulations of the distractor-task interplay.

Negative distractors generated significantly higher RTs than the positives, in both easy and difficult task conditions, without any difference in accuracy. In the easier condition, BAS dominance and trait impulsivity appeared to modulate task performance, highlighted by a significant inverse correlation between

questionnaires scores and task RTs in the presence of positive distractors.

Overall, our data suggest how cognitive load does not affect the advantage generated by positive distractors, which remained unaltered on the two difficulty levels. However, individual differences appear to modulate this advantage, only when the required cognitive load is low.

Positive distractors are therefore able to improve task performance significantly, compared to the negative ones, independent of the cognitive load associated.

5.2. Introduction.

Emotional stimuli have been found to affect the performance of an ongoing cognitive task. Whether identifying similar effects of positive and negative distractors on task completion, or detecting a stronger detrimental impact of the negative, compared to the positive, stimuli, past research agrees on their relevance even when not explicitly attended, possibly due to their relevance classically associated to the survival of the individual (Matthews and Gilliland, 1999). This influence has led to thinking that, for the fundamental role they play, emotional stimuli would receive prioritized processing at the brain level (Dolcos, Iordan & Dolcos, 2011). According to this theory, any ongoing non-emotional process would be queued and incoming emotionally salient stimuli would be automatically processed (Carretié, 2014; Carretié, Hinojosa, Martín-Loeches, Mercado & Tapia, 2004). Therefore, independent of the complexity of the task associated, emotional distractors would always be processed automatically, even if irrelevant at the task level.

Pessoa and colleagues (2002) proposed instead an alternative interpretation of this course: emotional distracting stimuli would not receive automatic processing, but would rather share the attentional resources available with the ongoing task. Under this perspective, the processing of emotional distractors would take place in parallel with the cognitive component, due to the availability of attentional resources to share between the two processes. The authors supported their theory with fMRI data showing how the activity in emotion-related areas –such as the amygdala- decreases in response to emotional distractors when the level of cognitive load required by the task increases. Fig. 13 illustrates, in a diagram, the core aspects of the two theories here described.

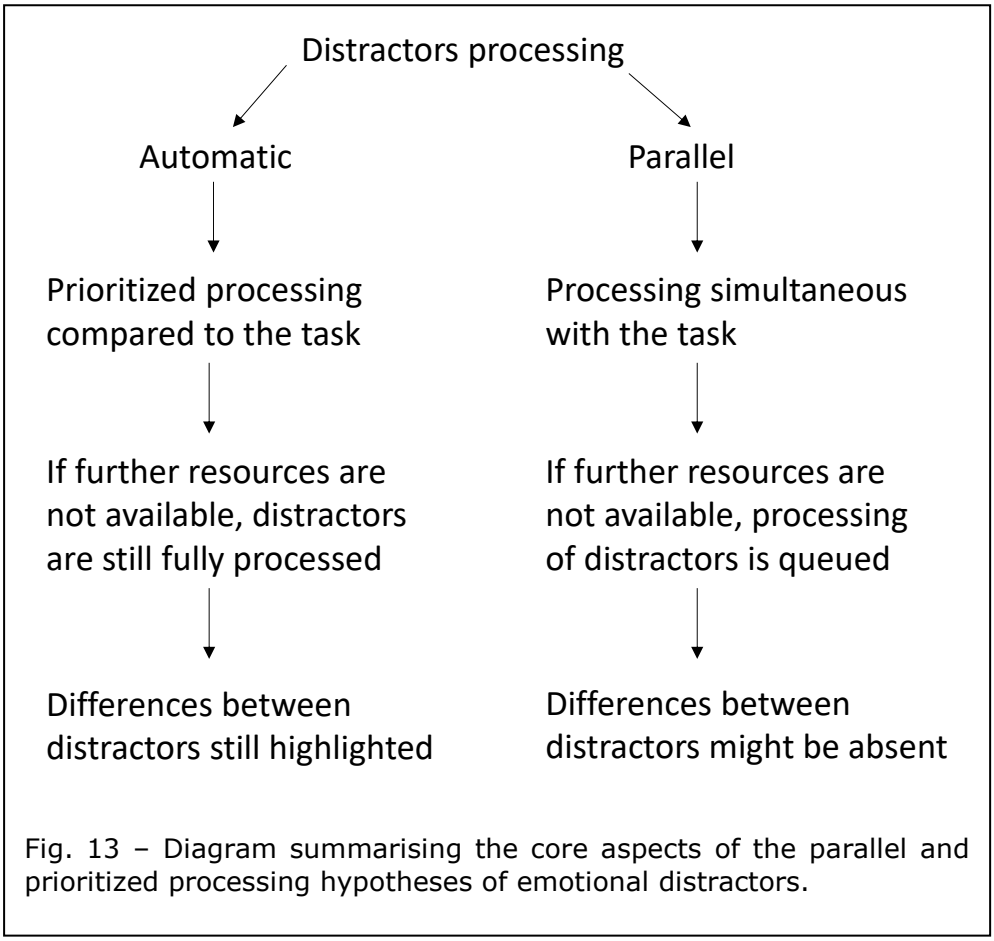


Fig. 13 – Diagram summarising the core aspects of the parallel and prioritized processing hypotheses of emotional distractors.

However, there is currently disagreement in the literature on the notion of "attentional resources" available. Most of the studies designed to assess the effects of emotional distractors did not employ tasks able to fully engage the attentional resources of the participants.

To modulate cognitive load, one of the most exploited tasks in psychological research is the Sternberg's delayed response paradigm (Sternberg, 1969). Participants are asked to store memoranda in memory and, in a second moment, compare it with a probe stimulus and state whether the probe matched (partially or totally) with the memoranda or not. This type of task requires a forced choice response: the participants always provide a response to the task. The memoranda used in past research have greatly varied in type: letters (Habeck et al., 2005; Raghavachari et al., 2001), numbers (Jensen & Tesche, 2002), pictures (Klimesch et al., 2001), faces (Druzgal & D'Esposito, 2001; Tuladhar et al., 2007), abstract forms (Gruber & Müller, 2005; Habeck, Rakitin, Steffener & Stern, 2012), to mention few of the exemplars using visual stimuli. This experimental paradigm has classically been used for two purposes: assessing whether the type of stimuli presented as memoranda would affect working memory storage and recollection, or controlling how different levels of cognitive load can affect working memory. The former question is often answered through a presentation, within the same experimental session, of –at least- two different types of memoranda, to control for differences in the accuracy of the responses provided (Gevins, Smith, McEvoy & Yu, 1997; Schack, Vath, Petsche, Geissler & Möller, 2002; van Vugt, Schulze-Bonhage, Litt, Brandt & Kahana, 2010). The latter instead is easily manipulated by increasing or reducing the number of elements in the memoranda, along with different ways of presenting the memoranda itself: for example,

simultaneous presentation of all the elements of the memoranda array or sequential presentation of one item at a time. Previous studies highlighted how the sequential presentation of the elements, especially at a slow pace, could facilitate the rehearsal of the elements in the array, particularly in case of verbal (alphabetical characters) and numerical stimuli (Donkin & Nosofsky, 2012; Okuhata, Kusanagi, Kawaguchi & Kobayashi, 2012).

Surprisingly, past research has weakly exploited the Sternberg paradigm in the study of emotional distraction, despite its theoretical versatility to serve the purpose. Few works used a distraction paradigm with task-irrelevant stimuli having no emotional salience (Bonnefond & Jensen, 2012, 2015; Gladwin, den Uyl, Fregni & Wiers, 2012). Other works used emotional pictures as distractors focusing, however, on different aspects of distraction (the study of working memory performance within the clinical population) or employing only negative emotional stimuli, therefore, not comparing the effects of positive Vs negative distractors (Oei et al., 2012; Oei, Tollenaar, Elzinga & Spinhoven, 2010). The majority of the works employing verbal stimuli (i.e. letters) to manipulate different levels of cognitive load share a common feature: the maximum number of stimuli presented was six in the high-load condition. This is considered a standard threshold beyond which performance significantly deteriorates.

Another variable often overlooked in the study of emotional distraction is the individual variability of the population sample analysed. Gray's dimensions of BIS/BAS dominance have been proved to be dramatically involved in the processing of affective stimuli (Corr, 2004; Gray, 1981). Behavioural dominance, along with the two associated traits of impulsivity and anxiety, appears

to modulate the behavioural and neurophysiological responses to affective cues (Gray, 1987).

Past research has demonstrated how BIS/BAS dominance can modulate the performance of participants undergoing a memory task (Balconi & Cobelli, 2014; Lim, Bruce & Aupperle, 2014). These works showed how the degree of BIS/BAS dominance influenced the performance of the participants. However, in the examples mentioned, both distractors and task-relevant elements had strong affective connotations, therefore it is unclear whether the same effect would be manifested in a task holding no emotional features and with different degrees of cognitive load required to its completion.

The aim of the current work was to assess the influence of positive and negative emotional distractors on the performance of a Sternberg's delayed response task, in which the memoranda had two levels of difficulty, easy and hard, to engage a different amount of cognitive resources to its completion. We also aimed to analyse the influence of individual personality traits, in the form of BIS/BAS dominance, trait impulsivity and trait anxiety, to assess whether these subjective differences can modulate the effects of the emotional distractors on task completion. We predicted that positive and negative emotional distractors would have a different effect on task performance, with a stronger deterioration due to negative stimuli. We also predicted that the effects of the affective distractors would be modulated by individual traits, with decreasing RTs in response to trials containing positive and negative distractors matching an increase of BAS dominance/impulsivity and BIS dominance/anxiety respectively.

5.3. Materials and methods.

5.3.1. Participants.

Thirty right-handed young adults (age: 24.0 ± 3.4 years; range: 19-32), 15 of them females, voluntarily agreed to take part in the study. Their laterality index was established using the Edinburgh handedness inventory (Oldfield, 1971): the mean laterality index was 89.5 ± 11.2; ranging between +68 and +100. The study received approval from the local Ethics Committee and, in accordance with the declaration of Helsinki, each participant gave informed written consent to participate before the beginning of the experiment. They received an inconvenience allowance at the end of the session.

5.3.2. Task and procedure.

At the beginning of the experimental session, participants completed a series of questionnaires to use as a self-reported measure of emotionally relevant personality traits. The questionnaires administered were: Carver-White questionnaire (Carver & White, 1994); Sensitivity to Reward/Punishment Questionnaire SPSRQ-35 (Torrubia, Ávila, Moltó & Caseras, 2001); Dickman's Impulsivity Inventory DII (Dickman, 1990); State-Trait Anxiety Inventory STAI-Y (Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983). They were used to establish, respectively, the degree of dominance for the Behavioural Activation/Inhibition Systems; the sensitivity to reward- and punishment-eliciting stimuli (which is an alternative way to measure BIS/BAS dominance), the level of trait impulsivity and the level of trait anxiety. The last two, according to Gray (1981), are the "operative traits" that would modulate the activity of the Activation and

Inhibition systems respectively and can be taken as measures of the BIS/BAS individual levels.

Immediately after, participants completed the Sternberg delayed response task interspersed with emotional distractors. As illustrated in Fig. 14, each trial started with a fixation cross displayed for 1000ms; then the memoranda, an array of letters, appeared on the screen for 1500ms followed by a distractor window for 2000ms; eventually, after a delay of 1000ms, a probe letter appeared for 500ms. Trials ended with an inter-trial interval of variable duration between 2000 and 4000ms after the probe letter offset (not shown in the figure).

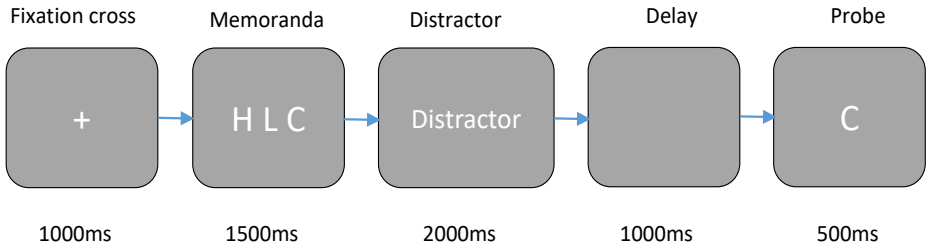


Fig. 14 – Timeline for the experimental design.

Participants were instructed to provide a response to each trial by pressing a key on an Apple computer keyboard, using only one hand per experimental block according to the instructions displayed on the screen. Using the index and middle fingers, they responded by pressing two different keys if the probe presented after the delay window was part of the memoranda array or not. The combination of keys was different for the two hands to ensure that no habituation effect influenced the responses. The onset of the probe letter on the pc screen marked the beginning of the time segment used to calculate RTs. Each participant completed four blocks of trials; two of the blocks required a response using the

right hand; two required a left-hand response. For each hand, one of the two blocks contained emotional pictures in the distractor window; the other block contained scrambled pictures and was used as a control condition over the emotional distractors. The emotional condition blocks were composed of 40 trials each; half of them contained a positive distractor, the remaining half a negative one. Moreover, within each valence level, half of the trials contained a 6-elements memoranda array, the other half a three-element array. Within each sub-condition, responses with the two fingers were evenly distributed (i.e. in half of the trials the probe was part of the array, in the other half it was not).

The control blocks were instead composed of 20 trials per block; within them, 10 trials contained a 6-elements array and the other half a 3-elements array. Within each subgroup, half of the trials had arrays containing the probe, while the other half did not. Before the actual start of each block, participants completed a short (5 trials) practice block to get familiar with the structure of the trials, the pace of the presentation and the keys to be pressed to provide their responses.

At the end of the four blocks, participants viewed a set of 20 emotional pictures, evenly split into positive and negative. They were asked to rate the pleasantness of each one on a 9-point scale; subsequently, they were asked to indicate whether the picture had been presented during the RT task or it was being displayed for the first time. Pictures were displayed for 3000ms and were preceded by a fixation cross, displayed for 2000ms, appearing on the screen after the responses to the antecedent trial were provided. Participants were unaware of the presence of this last block although were told, during the experiment, not to focus only on the cognitive task but to pay attention to the distractors too.

5.3.3. Preliminary analyses and results from pilot studies.

Through a series of pilot studies that followed a wide literature search, we decided to employ arrays of three or six letters in the low- and high-load conditions. The timing of the presentation (i.e. duration of the windows in which the memoranda array is presented and the duration of the retention period) were also established following the results of pilots studies, here omitted. The main aim of the pilot studies was to find a protocol suitable to study the effects of the distractors, therefore avoiding any ceiling effect or chance responses to the task. We chose to use a maximum of six elements in the high-load condition as this was the maximum number of elements to memorise within the temporal window available without a significant decrease of accuracy (<66.7% overall with more than six elements). For similar reasons, we employed three elements (instead of one or two) in the low-load condition, in order to avoid any ceiling effect, since with two-element arrays several participants reached 100% accuracy. To avoid any rehearsal effects during the retaining period, we decided to present all the elements in the memoranda simultaneously and removed from the pool of letters all the vocals to prevent the facilitation of recognition through assonances.

5.3.4. Stimuli used.

The memoranda arrays and the probe elements in the RT task were capital Latin characters of the English alphabet. In order to avoid any rehearsal of the memoranda array, we excluded vowels from the pool of letters used. For the same reason, we presented the full array in a single window, rather than presenting one element at a time in different temporal windows. The remaining 21

symbols were randomly combined into 3- or 6-elements strings through an in-house Matlab script, which controlled for the absence of repeated elements within each array and a homogeneous use of all the characters within the memoranda arrays and within the probe elements, for each experimental block. No sequence was repeated within the whole experiment. For the trials in which the probe was part of the memoranda array, the position of the matching letter was also counterbalanced within each experimental block, for both array lengths.

For the emotional condition of the RT task, we employed 40 positive and 40 negative pictures from the IAPS database as emotional distractors. Thirty-five of the stimuli for each valence level were the same used in the EEG study illustrated in chapter 3. The remaining 10 stimuli were selected on the same grounds as the previous ones: based on the normative ratings provided in the database, we picked stimuli rated between 1 and 3 on the arousal scale; the positive pictures had a valence rating between 7 and 9; the negative ones between 1 and 3.

In the control blocks, pictures held the same visual properties of the emotionally salient ones (luminance, colour frequency, etc.); however, the content of the picture was not detectable: therefore, the emotional salience was null. For further details on the generation of the scrambled pictures, please refer to the previous chapter, in the Materials and Methods section.

In the memory task that followed the RT task, we selected 10 positive and 10 negative pictures, 20% of which have been already presented during the RT task and the remaining 80% were new to the participants. The new pictures were selected on the same criteria for valence and arousal; the previously seen pictures were instead selected randomly within the pool of stimuli used in the RT

task. This experimental block setup was identical to the one used in the previous study.

5.3.5. Statistical analysis.

For the Carver-White questionnaire, overall BIS/BAS dominance was established by the means of t-tests on the average scores for the two Activation and Inhibition scales. We did not use overall scores due to the different number of items that each scale presents within the questionnaire. For the SPSRQ, sensitivity to reward/punishment has been calculated as the overall score of the two subscales due to the homogeneity in the number of elements present in each. The dominance of Reward-Punishment system was established by the means of t-tests on the overall score of the SP and SR subscales.

The degree of trait impulsivity and anxiety from the DII and STAI-Y questionnaires have been calculated as the overall score of each scale.

With regard to the behavioural data, the RTs for the emotional condition of the cognitive task have been analysed by means of 2 x 2 x 2 ANOVA (Hand: Left Vs Right; Difficulty: Easy Vs Hard; Valence: Negative Vs Positive). The same statistical test structure has been used to assess task accuracy.

The RTs for the control condition of the cognitive task have been analysed by means of 2 x 2 ANOVA (Hand: Left Vs Right; Difficulty: Easy Vs Hard). The same statistical test structure has been used to assess task accuracy.

For the memory task, both the valence ratings and the memory performance were analysed by means of paired t-test for the two valence levels (Negative Vs Positive). Two separate analyses were

conducted for the new pictures and the previously displayed distractors during the RT task.

Trait-performance correlations were calculated as Pearson's Correlation Coefficient between RTs in response to specific task conditions and individual scores for the behavioural dominance, the trait impulsivity and the trait anxiety scales. In particular, for the trials containing a positive distractor, RTs for both easy and hard difficulties have been correlated with BAS dominance, trait impulsivity and sensitivity to reward questionnaires scores. For the trials containing a negative distractor, RTs for both the easy and hard task difficulties have been correlated with BIS dominance, trait anxiety and sensitivity to punishment questionnaires scores.

The statistical threshold was set at $p < 0.05$ and we applied Bonferroni corrections for multiple comparisons where appropriate. Throughout the Results section, mean scores ± SE are reported.

5.3.6. Data pre-processing.

For the statistical analysis, we excluded the trials that received an incorrect response (errors). We marked as errors also the trials that received a double response, either if the first response was wrong and the second correct, or vice versa. Moreover, the trials that did not receive a response (missed trials) were considered as errors and therefore included in the accuracy, but not in the RTs, analysis.

After this first step and before the statistical analysis, we applied an outlier exclusion correction on single trials on the grounds of the individual speed of response. In particular, within each participant, we calculated the Means (Ms) and Standard Deviations (SDs) for the RTs in response to trials in the easy-difficulty and hard-difficulty condition, regardless of the distractor displayed, and

excluded from the analysis all the trials falling outside the range of M±2SDs within each difficulty level, as considered significantly anticipated or delayed responses. The trials excluded were not considered for the RTs nor the accuracy analyses in both the emotional and control conditions. The remaining trials were used for the statistical analysis illustrated in the previous subsection. Overall, in the current study, the rejection rate was inferior to 5% of the total trials; the highest rejection rate in a participant was 9.3%.

5.4. Results.

5.4.1. Behavioural dominance.

For the Carver-White questionnaire, no significant difference was found between the average BAS and average BIS scores. For the SPSRQ questionnaire, no significant difference was found between the SP and SR scales. In both tests, level of significance was $p>0.6$. Therefore, the behavioural dominance of the participants was heterogeneous and not driven towards one of the two systems.

5.4.2. RT task analysis: emotional condition.

For the RTs, there was a significant main effect of Difficulty ($F(1,29)=81.81$, $p<0.001$, partial $\eta^2=0.74$). Trials containing a 3-elements memoranda array received a significantly faster response compared to the ones containing a 6-elements memoranda array ($M_E=812\pm32$ms; $M_H=906\pm35$ms). We also found a main effect of Valence ($F(1,29)=4.25$, $p<0.05$, partial $\eta^2=0.13$). Trials containing a positive distractor received a significantly faster response compared to the ones containing a negative distractor

(M_P=847±34ms; M_N=870±33ms). We found no significant main effect for the Hand factor, nor any significant interaction between the main factors in the RTs analysis ($p>0.4$, $F<0.65$ in all cases).

For the accuracy scores, there was a significant main effect of Difficulty ($F(1,29)=44.37$, $p<0.001$, partial $\eta^2=0.61$). Accuracy in response to trials containing a 3-elements memoranda array was significantly higher compared to the ones containing a 6-elements memoranda array (M_E=94.7±1.0%; M_H=84.1±1.6%). No significant main effects of the other two factors, nor any interaction between the main factors were found for the accuracy scores ($p>0.15$, $F<2.25$ in all cases).

5.4.3. RT task analysis: control condition.

For the RTs, there was a significant effect of Difficulty ($F(1,29)=21.20$, $p<0.001$). Trials containing a 3-elements memoranda array received a significantly faster response compared to the ones containing a 6-elements memoranda array (M_E=796±35ms; M_H=902±36ms, partial $\eta^2=0.48$). We found no significant main effect for the Hand factor, nor any significant interaction between the main factors in the RTs analysis ($p>0.2$, $F<1.38$ in all cases).

For the accuracy scores, there was a significant main effect of Difficulty ($F(1,29)=20.08$, $p<0.001$, partial $\eta^2=0.41$). Accuracy in response to trials containing a 3-elements memoranda array was significantly higher compared to the ones containing a 6-elements memoranda array (M_E=93.5±0.9%; M_H=86.0±1.3%). No significant main effect for the Hand factor, nor any interaction between the main factors were found for the accuracy scores ($p>0.5$, $F<0.43$ in all cases).

5.4.4. Combined analysis on RTs and accuracy for the emotional and control conditions.

In a second stage, we repeated the analysis on RTs and included the response time to the scrambled pictures. We found a significant effect for the Complexity factor ($F(1,29)= 63.04$, $p<0.001$, partial $\eta^2=0.69$). RTs in response to trials presenting a memoranda array of three elements were significantly lower than the ones presenting a memoranda array of six elements ($M_E=612\pm44$ms; $M_H=652\pm44$ms). The remaining effects were not significant ($p>0.1$, $F<2.30$).

Despite the non-significant effect of the valence factor (nor of its interactions with any other factor analysed), we ran a pairwise comparison test between the three levels to control for the relative increase or decrease of RTs in the emotional conditions compared to a non-emotional baseline. The mean RTs for the scrambled distractors ($M_S=849\pm33$ms) were intermediate between the positive and the negative RTs ($M_P=847\pm34$ms; $M_N=870\pm33$ms). In the pairwise comparison between the scrambled distractors RTs and both the positive and negative distractors RTs, both contrasts resulted non-significant ($p>0.3$).

We also repeated the same analysis for the accuracy scores, including once again the scrambled distractors as a third level in the Valence factor. We found a significant effect of the Complexity factor ($F(1,29)= 52.20$, $p<0.001$, partial $\eta^2=0.64$). Accuracy in response to trials presenting a memoranda array of six elements were significantly lower than the ones presenting a memoranda array of three elements ($M_E=94.3\pm0.8\%$; $M_H=84.7\pm1.3\%$). The remaining effects were not significant ($p>0.1$, $F<2.20$).

Despite the non-significant effect of the valence factor (nor of its interactions with any other factor analysed), we ran a pairwise comparison test between the three levels to control for the relative increase or decrease of accuracy scores in the emotional conditions

compared to a non-emotional baseline. The mean accuracy for the scrambled distractors (M_S=88.8±1.6%) was almost identical to the positive and the negative ones (M_P=89.7±0.8%; M_N=89.9±1.0%). In the pairwise comparison between the scrambled distractors accuracy scores and both the positive and negative distractors accuracy scores, both contrasts resulted non-significant ($p>0.9$).

5.4.5. Memory task and rating task analyses.

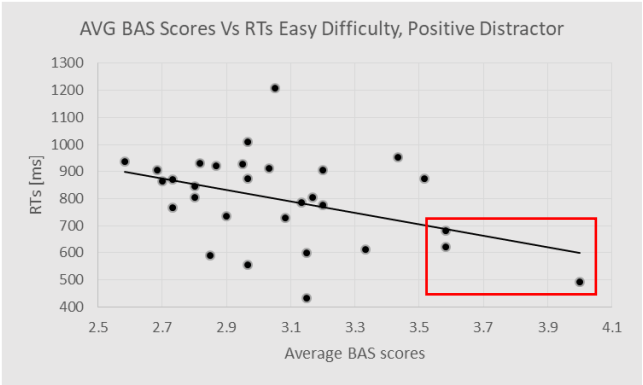
For the previously displayed distractors, we found no significant differences in the accuracy of mnemonic recall for positive and negative distractors ($p>0.35$).

For the new pictures, we found a significant difference in the accuracy of classification of positive and negative stimuli ($t=2.90$, $p<0.005$). Accuracy in the classification of positive pictures as new was significantly worse than the classification of negative pictures (M_P=86.1±12.7%; M_N=92.4±10.4%).

For the rating task, there was a significant difference between the ratings to positive and negative pictures ($t=23.30$, $p<0.001$). Positive pictures received significantly higher ratings than the negative pictures (M_P=7.36±0.71; M_N=3.16±0.64).

5.4.6. Trait-performance correlations.

In the Easy difficulty condition, there was a significant inverse correlation between the RTs in the presence of positive distractors and scores of both BAS dominance (PCC=-0.40, $p<0.03$) and trait impulsivity (PCC=-0.41, $p<0.03$) (Fig. 15).



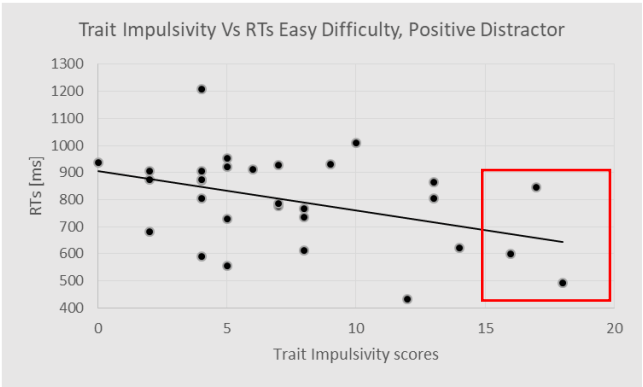


Fig. 15 – Pearson's correlation between task RTs (responses to trials containing 3-elements memoranda arrays and positive distractors) and BAS average dominance (top); Pearson's correlation between task RTs (responses to trials containing 3-elements memoranda arrays and positive distractors) and trait Impulsivity scores (bottom). The extreme values considered for the outlier removal analysis have been highlighted in a red rectangle in both graphs.

Participants with progressively higher BAS dominance and trait impulsivity scores provided progressively faster responses to trials with three elements in the memoranda array containing a positive distractor.

The same correlation was non-significant in the Hard difficulty condition. The correlations between the RTs in the presence of negative distractors and scores of BIS dominance or trait anxiety did not reach the level of significance in either difficulty condition.

To control for the effects that a single outlier can have on the correlation analysis, the analysis was repeated removing, one at a time, the participants with the highest behavioural self-reported measures. Specifically, we removed from the analyses the participants with the highest BAS average scores and the highest trait impulsivity scores, repeating the correlation analysis without one of the three participants at a time. We applied this further control on the data to ensure a strong outlier did not drive the significance of the correlation analysis, but it actually reflected the average behaviour of the population sample analysed. For both correlation analyses, with BAS averages and trait impulsivity scores, the calculation was repeated three times, removing one outlier at a time. In all cases, and for both the BAS dominance and the trait impulsivity scores, the correlation analysis remained significant at $p<0.05$ level. Bonferroni correction for multiple comparisons has been applied to both analyses. In Fig. 13, the values considered for this analysis have been included in a red rectangle.

5.5. Discussion.

In the present study, we examined the effects of positive and negative emotional distractors on the completion of a delayed response memory task, analysing the influence of distracting stimuli on different levels of task difficulty. We also aimed to control whether individual differences in terms of behavioural dominance would influence the interaction between emotional distractors and task performance. Moreover, the use of the same emotional distractors in our previous experiment would allow a direct comparison of the effects of affective stimuli on two different types of task.

The analysis of behavioural measures pointed out a significant advantage in task performance brought in by positive distractors, in terms of faster responses without any significant difference in accuracy rates. The higher level of cognitive load brought in a significant deterioration of task performance, which however was not reflective of an influence of the emotional distractors since it was simultaneously present in a control condition with scrambled, non-emotional pictures replacing the affective stimuli. In both cases, in fact, performance significantly worsened, in terms of higher RTs and lower accuracy, in the difficult condition compared to the easier one.

Valence did not modulate mnemonic recollection of emotional distractors, confirming the results of the previous study, as the accuracy in the recall of positive and negative stimuli was not significantly different. However, when displayed new stimuli, participants were significantly less accurate in stating that a positive picture had not been presented as a distractor, compared to the performance in response to negative stimuli.

Despite the absence of a clear behavioural dominance in the sample analysed, the presence of positive distractors led to significantly faster RTs in task response, independent of task difficulty. However, we found a significant correlation between the performance (RTs) in the easier task condition when a positive distractor was presented and both degree of BAS dominance and trait impulsivity.

5.5.1. Task performance: effects of positive and negative distractors at the behavioural level.

The analysis of task performance highlighted how the presence of positive distractors led to a significant advantage in task performance, compared to the negative ones. Trials displaying a

positive picture between the memoranda array and the letter probe received a significantly faster response, without any loss in terms of accuracy scores.

In the current literature, very few works have analysed the effects of emotional distractors using the Sternberg task (Oei et al., 2012, 2010). In these studies, the decrease in task performance associated with the presence of negative distractors was contrasted only against a neutral baseline rather than the positive counterpart. However, several works in the literature have previously pointed out the advantage for positive distractors using other cognitive tasks interspersed with emotional distractors, especially retrieved from the IAPS database (Hindi Attar, Andersen & Müller, 2010; Weinberg & Hajcak, 2011). Overall, our results are in agreement with the current studies that highlighted different effects of positive and negative distractors, with a precise direction of this difference: positive distractors, compared to the negative, having a less disruptive influence on task performance.

Interestingly, this effect is independent of the behavioural dominance of the participants: the current population sample had, in fact, heterogeneous behavioural dominance. This result, in combination with what was obtained from the correlation analyses that will be illustrated in the following sections, allows suggesting a different interpretation of the role that personality traits can have in the context of emotional distraction. In fact, according to our results, the behavioural dominance appears to be more of a modulating than an absolute factor in the interaction. The presence of positive distractors per se, interacting with the ongoing task, would generate significantly faster responses compared to the negative ones. However, the degree of this advantage appears to be modulated, in both cases, by the behavioural dominance and the personality traits analysed. Therefore, especially in the case of

low-arousing emotional stimuli, the effects of positive pictures stably led to significant advantages in task performance, in terms of faster RTs without trade-off effects on accuracy rates, independent of the individual sensitivity to rewarding stimuli.

The second analysis we ran on the RTs for this study, including the scrambling distractors as a third level in the Valence factor, confirmed what found in the previous study in terms of relationship between emotional distractors and a non-emotional baseline. In fact, also in the current study, the RTs in response to trials containing scrambled distractors did not differ significantly from the RTs recorded in presence of positive or negative distractors. However, we noticed a decrease in RTs due to the presence of positive distractors in comparison to a non-emotional baseline and, simultaneously, an increase of RTs due to the presence of negative distractors in comparison to the same baseline. Once again, this result allows us to describe the effects of positive distractors in terms of "improving performance" not only when compared to another emotional condition (the negative distractors), but also with a neutral condition. In parallel, we can describe as "detrimental" the effects of negative distractors not only due to the increase in RTs when compared to a positive counterpart, but also with respect to a non-emotional baseline. The described effects do not manifest at the expenses of task accuracy, since this parameter resulted identical in the three conditions analysed. Therefore, as mentioned for the analysis on Study 1, despite the non-significance of the statistical test, this second analysis allows us to put in context the effects of task distractors not only in terms of relative difference between two valence levels, but also compared to a non-emotional condition.

5.5.2. The effects of task demands and emotional distraction on different levels of cognitive load.

In the current study, experimental manipulation (task difficulty) did not interact significantly with the valence of the emotional distractors. There was a significant main effect of task difficulty, independent, however, of the presence of the distractors as detected in both the emotional and control experimental conditions. In both cases, participants provided significantly slower and more inaccurate responses when trials contained a 6-elements memoranda array, compared to the ones with only three elements. This effect, manifested at both emotional and control conditions levels, allows us to conclude that, from a purely cognitive perspective, there is a significant increase in task demands between the easier and the difficult conditions. The task proposed could, therefore, be considered suitable to study emotional distraction under two different levels of cognitive load. Further confirmation comes from works in the literature (Kirschen, Chen, Schraedley-Desmond & Desmond, 2005; Payne & Kounios, 2009; Veltman, Rombouts & Dolan, 2003) in which similar tasks have been employed. In these studies, the number of alphabetical characters presented during each trial varied between two and seven, as those are considered the floor and ceiling thresholds respectively for the number of items in working memory tasks.

In our study, in the emotional condition, the valence of the distractors influenced task performance, independent of its difficulty in a homogeneous way. The valence of the task-irrelevant affective stimuli did not significantly interact with the task difficulty, but the advantage generated by the positive distractors was independent of the cognitive demands of the task. This result is in agreement with several other works (Berggren, Koster & Derakshan, 2012; Hajcak, Dunning & Foti, 2007; Hindi Attar &

Müller, 2012). Although task demands were manipulated in different ways, all these studies share the common finding of an absence of modulation, in terms of behavioural measures and brain imaging data, of the effects of emotional distractors by different levels of task demands. However, it must be noticed how most of the previous studies did not compare the results of an emotional condition with a non-emotional baseline, in order to better isolate and characterize the effects of the distractors.

5.5.3. Memory task performance: the absence of modulation by valence in the mnemonic recall.

In this study, we separately analysed the mnemonic classification of newly and previously displayed emotional stimuli to distinguish the effects of type I and type II errors on the memory task. For the recall of the pictures that have been displayed as emotional distractors during the RT task, we found no significant differences across the two valence levels. This result confirms what was found in our first experiment, and is in agreement with the wealth of studies suggesting an absence of significant differences in the recall of positive and negative emotional pictures while considering arousal the main modulator of the mnemonic recall.

Therefore, the advantage in task performance brought in by the positive distractors cannot, in principle, be explained in terms of a lack of attention towards the stimuli, since the recall rate did not significantly differ between the two valence levels. As the recall rates were similar for positive and negative distractors, with an overall accuracy well above the chance threshold (>70% overall), we can safely accept that participants devoted the same attentional resources to stimuli belonging to each valence level. Standing this assumption, it is possible to link the advantage in task completion not to a difference in terms of attention to the

stimulus itself but, possibly, to a difference in the ability to disengage attention from the stimulus and recover it back to the task. The concept is not new in the literature: other works suggested that, compared to the positive ones, negative distractors engage attentional and cognitive resources more powerfully, making it harder to disentangle attention from the stimulus (Anticevic, Barch & Repovs, 2010; Iordan & Dolcos, 2015).

A similar line of argument can be applied to the analysis of newly displayed stimuli, in which negative pictures, compared to the positives, have been classified significantly better. This result is in agreement with other works present in the literature which, similarly, found that participants classify new negative stimuli better than positives, while for the previously presented stimuli, arousal –and not valence- modulated the recall (Fernández-Rey & Redondo, 2007; Ochsner, 2000). The novelty in the results of the current study, compared to the vast majority analysing mnemonic recall and classification of emotional stimuli, lies in the role of the stimuli themselves. In fact, while in the previous studies, the elements in the group of "seen" stimuli were explicitly attended by the participants, as part of a task (for example, a valence/arousal rating task) or actively encoded, here we used task-irrelevant elements as previously seen stimuli. Therefore, we suggest here that the pattern of results found in previous research on mnemonic encoding and recall of emotional stimuli could potentially be extended to task-irrelevant emotional distractors as well since, from a purely behavioural point of view, the pattern of accuracy in the responses is symmetrical in both cases.

5.5.4. Trait-performance correlations: the modulation effect of the activation system.

While the analysis of task performance highlighted a significant improvement in its completion deriving from the presence of positive distractors, compared to the negatives, the analysis of the correlation between task performance and personality traits underlines another fundamental link between emotional perception and cognitive performance. In fact, both the degree of BAS dominance (i.e. the disposition to engage appetitive stimuli, as the positive distractors are) and trait impulsivity (an extrinsic measure of BAS dominance) inversely correlate with the time needed to complete the task, under the condition that it requires low cognitive resources. While an overall advantage appears to depend on the valence of the distractors, the magnitude of this advantage is partially modulated by individual personality traits. Past research underlined how the level of BAS dominance correlated with better task performance in the presence of positive emotional stimuli (Gomez & Gomez, 2002). However, in this case, the emotional stimuli were explicitly attended and not presented as task-irrelevant elements.

In our study, this association with BAS dominance was expressed through the correlation analysis only when the task required lower cognitive resources for its completion. We interpreted this result in terms of attentional resources devoted to the processing of the emotional distractors. While the cognitive load required by the task is low, more attentional resources can be assigned to the processing of the distractors (Pessoa et al., 2002). This processing is facilitated by the increase in BAS dominance, when the stimulus is positive. Therefore, the distracting power of the affective stimuli decreases, allowing a faster response to the task: the degree of BAS dominance modulates this process. Simultaneously, in the

harder task condition, less attentional resources are offered to the processing of the distractors, therefore this modulatory effect appears to be non-significant. This datum would support the idea that the processing of irrelevant affective stimuli would be competitive rather than automatic.

Finally, another element of novelty brought in by the current study is that a link between cognitive and emotional processing is expressed through the modulatory effect of individual personality traits with regard to positive distraction. Fox and colleagues (2012) pointed out how "the impact of fear conditioning on attention is modulated by individual variation in trait anxiety when the perceptual load is low" (p. 236). However, in their case, a specific emotion, rather than a whole valence level, was analysed. Our results extend the previous findings to a valence level rather than one specific emotion, and complement what was found for trait anxiety with an analysis on trait impulsivity.

5.5.5. Limitations of the current study and future directions.

In the current study, we tested the effects of positive and negative distractors on the completion of a cognitive task, manipulating the cognitive load as an experimental variable. Similarly to what we found in the first experiment, behavioural data suggested a significant advantage in task performance brought in by positive distractors irrespective of the task difficulty level. Moreover, in the low-load condition, this advantage appears to be modulated at the individual level by personality traits describing behavioural approach dominance.

However, one limitation of the first two experiments is the use of the same distractors, although within completely different types of

task. The question that spontaneously arises is whether this consistency in the results is actually due to the valence of the stimuli, or perhaps to the *type* of distractors employed. For this reason, the following work will focus on the direct comparison of two different types of emotional distractors, in order to assess whether the aforementioned effects are related to the valence level of the stimuli or to other features. To allow this direct contrast, two different visual stimuli must be employed, in conjunction with a type of task that would not create emotionally unrelated interferences with either type. In addition, since they appear to be salient in the modulatory effects of the emotion-cognition interplay at the individual level, the analysis will include once again the personality traits linked to the dimensions of BIS and BAS dominance to establish a link between the type of distractors and their perception within the individual.

6. Emotional distracting words and pictures differently affect cognitive task performance.

6.1. Abstract.

Pictorial and written stimuli are among the most employed affective elements in emotional distraction studies. Several authors theorised a different impact of these when used as task-irrelevant components, on the grounds of a higher emotional salience for the pictorial ones. However, very few works have directly compared the effects of the two types of distractors on task performance.

The present study aimed at comparing directly how emotional words and pictures, respectively from the Warriner and NAPS databases, influenced the completion of a numerical magnitude comparison task. We also tested whether a different affective salience between words and pictures would result in dissimilar post-task mnemonic recollection rates. Twenty right-handed young adults completed the two tasks, along with several questionnaires to outline their affective dominance (BIS/BAS).

Task reaction times (RTs) and response accuracy provided quantitative information on the interference of the distractors on task performance. Questionnaires scores were correlated with performance data to analyse individual modulations of the distractor-task interplay.

While the results from the numerical task performance highlighted some differences in the effects of the emotional words and pictures on its completion, analysis of the mnemonic recall task pointed out significant dissimilarities in the accuracy rates for the written and pictorial distractors, the latter being significantly higher. Trait-

performance correlations suggested that the modulatory effect of personality traits on task responses appeared to be stronger for the emotional pictures than the words.

Overall, our data suggest a different impact of affective words and pictures on task performance, possibly due to the higher affective salience of the latter.

6.2. Introduction.

The results from the studies presented in the previous two chapters of this thesis suggested a significant advantage for the responses to task trials containing positive distractors in comparison to negative ones, independent of the type of task employed. Moreover, individual traits of BAS dominance and impulsivity appeared to be relevant in the modulation of this advantage at the participant's level. However, in both experiments, we only employed emotional pictures as distracting elements to test their influence on task performance.

Along with emotional pictures, past research has widely exploited affective words in emotion-related experiments (Imbir, 2017; Imbir, Spustek, Bernatowicz, Duda & Żygierewicz, 2017; Jacobs, 2017; Martin & Altarriba, 2017; M. Zhang, Ge, Kang, Guo & Peng, 2018; Y. Zhang et al., 2001). Emotional words have been previously used in emotional distraction research as task-irrelevant elements; however, several studies did not find significant differences in the effects of positive and negative words on task performance (Carou et al., 2011; Jackson, Linden & Raymond, 2012; Trauer, Andersen, Kotz & Müller, 2012). This behaviour, in terms of effects of the two levels of valence on task performance, appears to be in contrast with what has been detected for the pictorial counterpart. On the other hand, other studies determined

a modulatory effect of personality traits (BIS/BAS dominance) on both the perception of emotional words as task-irrelevant elements and on their subsequent influence on the task (Balconi & Cobelli, 2014). This second behaviour appears to be similar to that described for the emotional pictures.

These comparisons are, however, purely qualitative. Moving a step forward, other works have tried to outline a relationship between the processing of emotional words and pictures through a direct comparison of the two, suggesting significant differences between written and pictorial stimuli (Herbert, Junghofer & Kissler, 2008; Hinojosa, Carretié, Valcárcel, Méndez-Bértolo & Pozo, 2009; Houwer & Hermans, 1994). These studies often agreed in considering emotional salience of words as weaker than the pictures, meaning that the attentional resources devoted to the processing of words are inferior to the pictures, which can, in turn, have higher distracting power when used as task-irrelevant components. With regard to the comparative rating of emotional words and pictures, some studies reported a positivity offset for words and a negativity bias for pictures (Bayer and Schacht, 2014; Kensinger and Schacter, 2006). It means that positive words are rated higher than positive pictures and negative pictures are rated lower than negative words when arousal levels are matched. Positive valence would, in fact, enhance verbal working memory, directly linked with the words domain, while negative affect would enhance spatial working memory, linked with the pictorial stimuli domain (Gray, 2004; Storbeck, 2012).

In the field of emotional distraction, the direct comparison between words and pictures is virtually absent. As pointed out by Bayer and Schacht (2014), "only a relatively small number of studies has realized direct, that is within-subject, comparisons of emotion effects between stimulus domains; to the best of our knowledge,

none of them employing all three visual domains mentioned above at the same time and under comparable task demands [i.e. emotional words, pictures and faces]" (p. 2). These works always aimed at contrasting the effects of emotional words and pictures when they were explicitly attended during the experimental protocol; when employed as task-irrelevant elements in the context of cognitive processing and task completion, this direct comparison has never been performed to our knowledge.

Due to the theorised differences between the two types of stimuli, it is impossible, in principle, to rule out the possibility that the effects of emotional distractors on task performance highlighted in the first two studies we performed derive exclusively from the valence level of the stimuli or, instead, whether the type of stimulus employed could play a significant role. The aim of the present study is to contribute to the reduction of this theoretical gap by designing an experiment that compared directly the effects of emotional distracting words and pictures on the completion of a task. We selected a numerical magnitude comparison task since any task involving words or letters recognition (as the Sternberg task illustrated in the second experiment) would have created unwanted interferences between distracting words processing and task completion since the two stimuli would have belonged to the same domain.

Due to the differences highlighted from previous studies on the salience of the two types of stimuli, we predicted a different interaction between the valence levels and the type of stimuli. Moreover, we predicted a possible advantage for emotional pictures, in comparison to the words, in the recall of the task-irrelevant stimuli as the higher emotional charge of the pictures would facilitate their mnemonic classification and recall compared to the words.

6.3. Materials and methods.

6.3.1. Participants.

Twenty right-handed young adults (age: 25.0 ± 2.8 years; range: 20-31), 10 of them females, voluntarily agreed to take part in the study. Due to the presence of emotional words as distractors within the task, we selected only native English speakers, to ensure the full comprehension of the stimuli used. Their laterality index was established using the Edinburgh handedness inventory (Oldfield, 1971): the mean laterality index was 88.8 ± 14.0; ranging between +60 and +100. The study received approval from the local Ethics Committee and, in accordance with the declaration of Helsinki, each participant gave informed written consent to participate before the beginning of the experiment. They received an inconvenience allowance at the end of the session.

6.3.2. Task and procedure.

At the beginning of the experimental session, participants completed a series of questionnaires to use as a self-reported measure of emotionally relevant personality traits. The questionnaires administered included: Carver-White questionnaire (Carver & White, 1994); Sensitivity to Reward/Punishment Questionnaire SPSRQ-35 (Torrubia, Ávila, Moltó & Caseras, 2001); Dickman's Impulsivity Inventory DII (Dickman, 1990); State-Trait Anxiety Inventory STAI-Y (Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983). They were used to establish, respectively, the degree of dominance for the Behavioural Activation/Inhibition Systems; the sensitivity to reward- and punishment-eliciting stimuli (which is an alternative way to assess BIS/BAS dominance), the level of trait impulsivity and the level of trait

anxiety. The last two, according to Gray (1981), are the "operative traits" that modulate the Activation and Inhibition systems respectively and can be taken as measures of the BIS/BAS individual levels.

Immediately after, they completed a numerical magnitude comparison task interspersed with emotional distractors. As illustrated in Fig. 16, each trial started with a fixation cross displayed for 1000ms; then a first number appeared on the screen for 1500ms followed by a distractor window for 2000ms; eventually, after a delay of 1000ms, a second number appeared for 500ms. Trials ended with an inter-trial interval of variable duration between 2000 and 4000ms after the second number offset (not shown in the figure).

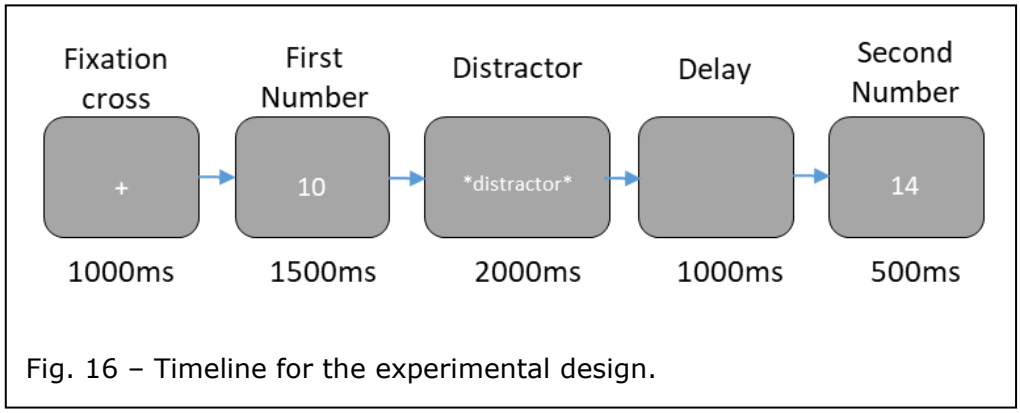


Fig. 16 – Timeline for the experimental design.

Participants were instructed to provide a response to each trial by pressing a key on an Apple computer keyboard, using only one hand per experimental block according to the instructions on the screen. Using the index and middle fingers, they were asked to respond by pressing two different keys if the second number presented after the delay window was smaller or bigger in value compared to the one presented before the distractor. The

combination of keys was different for the two hands to ensure that no habituation effect influenced the responses. The onset of the second number on the pc screen marked the beginning of the time segment used to calculate RTs. Each participant completed four blocks of trials; two of the blocks required a response using the right hand; two required a left-hand response. For each hand, one of the two blocks contained emotional pictures in the distractor window; the other block contained instead emotional words. Each block was composed of 30 trials; half of the trials contained a positive distractor, the remaining half a negative one. Within each condition, responses with the two fingers were evenly distributed (i.e. in half of the trials the first number was bigger than the second was, in the other half it was smaller); valence of the distractors was also balanced for each response finger. Before the actual start of each block, participants completed a short (five trials) practice block to get familiar with the structure of the trials, the pace of the presentation and the keys to be pressed to provide their responses.

At the end of the four blocks, participants viewed a set of 20 emotional pictures and 20 emotional words, evenly split into positive and negative. They were asked to rate the pleasantness of each one on a 9-point scale; subsequently, they stated whether the stimulus had been presented during the RT task or it was being displayed for the first time. Stimuli were displayed for 3000ms and were preceded by a fixation cross, displayed for 2000ms, appearing on the screen after the responses to the antecedent trial were provided. Participants were unaware of the presence of this last block although were told, during the experiment, not to focus only on the cognitive task but to pay attention to the distractors too.

6.3.3. Stimuli used.

In the current experiment, the emotional pictures have been retrieved from the Nencki Affective Picture System (NAPS) database (Marchewka, Żurawski, Jednoróg & Grabowska, 2014), instead of the IAPS. This new database of emotional pictures aims to increase the breadth of the IAPS (of which it mimics even the name) and other similar catalogues, trying at the same time to overcome some issues as the uneven distribution of the stimuli across the different contents. The NAPS is identical to the IAPS in terms of validation criteria and rating scales, with the only – possibly negligible- difference of a validation process through mainly European, rather than North-American participants. The clear advantages of this new database are a wider choice in the stimuli available (over 1300 pictures overall) with different content and a validation process that allows direct comparison with the results of studies using stimuli from the IAPS. In addition, this prevents risk of any habituation effect from participants who might have been previously exposed to IAPS pictures, since past research emphasized how habituation effects influence the perception of emotional stimuli (Codispoti, de Cesarei, Biondi & Ferrari, 2016; Itkes, Kimchi, Haj-Ali, Shapiro & Kron, 2017; Olofsson, Nordin, Sequeira & Polich, 2008). Repetitive display of the same stimuli can alter physiological response to them (leading eventually to the same response reserved to neutral stimuli) and, in the context of emotional distraction, lose the influence the stimuli have when first displayed (in terms of non-altered RTs in task performance).

The emotional words have instead been retrieved from the Warriner database (Warriner, Kuperman & Brysbaert, 2013), which catalogued a series of emotional words (in the specific example, around 14.000) on the very same grounds of the IAPS database,

with regard to dimensions considered (valence, arousal and dominance), scales used, validation criteria and internal consistency.

For the numerical magnitude task, we selected numbers between 1 and 20. For both response keypresses and across all blocks of trials, we kept constant the distribution of the first and the second number values employed, along with the average numerical distance (i.e. the absolute value of the difference) between the two numbers. We also controlled that no same pairs of numbers were shown in the same experimental block and that the possible repetitions of the same pairs of numbers were not associated with the same type of stimulus or valence level. The creation of the pair of numbers presented in each trial and their association with the relative distractor has been done through an in-house Matlab script.

For the RT task, we employed 24 positive and 24 negative pictures from the NAPS database and 24 positive and 24 negative words from the Warriner database as emotional distractors. The stimuli were selected on the same grounds as the previous experiments. Based on the normative ratings provided in the databases, both using the same criteria, scales, validation methods and internal consistency of the IAPS database, we picked stimuli rated between 1 and 3 on the arousal scale; the positive stimuli had a valence rating between 7 and 9; the negative ones between 1 and 3.

In the memory task that followed the RT task, we selected 20 positive and 20 negative stimuli, half of which were pictures and half words per valence level, 20% of which have been already presented during the RT task and the remaining 80% were new to the participants. The new stimuli, both words and pictures, were selected on the same criteria for valence and arousal; the previously seen distractors were instead selected randomly within

the pool of stimuli used in the RT task. This experimental block was identical to the one used in the previous two studies.

For the pictures, within each valence level, we balanced the choice in terms of content (people, objects, animals, human faces and natural scenes) and physical properties. For the words, we selected only verbs with abstract content and a total length between three and eight letters (i.e. love, hate). We excluded words strongly related to motor actions (i.e. 'push', 'pull') since they could potentially alter the RTs between the dominant and non-dominant hand (Dreyer et al., 2015; Pulvermüller, 2013; Pulvermüller, Moseley, Egorova, Shebani & Boulenger, 2014). A word has been categorized as abstract if it "describes internal states of the body", in contrast to action words, which are "semantically related to actions typically performed by moving different parts of the body (such as "talk" and "walk"), which activate body-part–specific representations in sensorimotor cortex" (Moseley, Carota, Hauk, Mohr & Pulvermuller, 2012, p. 1635). Action words can have also positive and negative valence (for example, "hug" Vs "stab"). Therefore, for the purpose of this study, both categories of words could have been employed with equally valid choice criteria since both fall under the definition of "emotional words". However, their link with motor execution is tighter and can lead to differences in task performance between the dominant and non-dominant hand due to the mapping, planning and execution of the action expressed by the word. For this reason, we decided to employ exclusively abstract words.

6.3.4. Statistical analysis.

For the Carver-White questionnaire, overall BIS/BAS dominance was established by the means of t-tests on the average scores for the two Activation and Inhibition scales. We did not use overall

scores due to the different number of items that each scale presents within the questionnaire. For the SPSRQ, sensitivity to reward/punishment has been calculated as the overall score of the two subscales due to the homogeneity in the number of elements present in the two. The dominance of Reward-Punishment system was established by the means of t-tests on the overall score of the SP and SR subscales.

The degree of trait impulsivity and anxiety from the DII and STAI-Y questionnaires have been calculated as the overall score of each scale.

With regard to the behavioural data, the RTs for the cognitive task have been analysed by means of 2 x 2 x 2 ANOVA (Hand: Left Vs Right; Type: Picture Vs Word; Valence: Negative Vs Positive). The same statistical test structure has been used to assess task accuracy.

For the memory task, performance was analysed by means of 2 x 2 ANOVA (Type: Picture Vs Word; Valence: Negative Vs Positive). Two separate analyses were conducted for the new stimuli and the previously displayed distractors during the RT task.

Trait-performance correlations were calculated as Pearson's Correlation Coefficient between RTs in response to specific task conditions and individual scores for the BIS/BAS dominance, trait impulsivity and trait anxiety scales.

The statistical threshold was set at $p < 0.05$ and we applied Bonferroni corrections for multiple comparisons where appropriate. Throughout the Results section, mean scores ± SE are reported.

6.3.5. Data pre-processing.

For the statistical analysis, we excluded the trials that received an incorrect response (errors). We marked as errors also the trials that received a double response, either if the first response was

wrong and the second correct, or vice versa. Moreover, the trials that did not receive a response (missed trials) were considered as errors and therefore included in the accuracy, but not in the RTs, analysis.

After this first step and before the statistical analysis, we applied an outlier exclusion correction on individual trials on the grounds of the individual speed of response. In particular, within each participant, we calculated the Means (Ms) and Standard Deviations (SDs) for the trials containing a picture or a word in the distractor window and excluded from the analysis all the trials falling outside the range of M±2SDs within each distractor type level, as considered significantly anticipated or delayed responses. The trials excluded were not considered for the RTs nor the accuracy analyses. The remaining trials were used for the statistical analysis outlined in the previous subsection. Overall, in the current study, the rejection rate was inferior to 5% of the total trials; the highest rejection rate in a participant was 9.2%.

6.4. Results.

6.4.1. Behavioural dominance.

For the Carver-White questionnaire, no significant difference has been found between the average BAS and average BIS scores. For the SPSRQ questionnaire, no significant differences have been found between the SP and SR scales. In both tests, the level of significance was $p>0.3$. Therefore, the behavioural dominance of the participants was heterogeneous and not driven towards one of the two systems.

6.4.2. RT task analysis.

For the RTs, there was a significant Hand x Valence interaction ($F(1,19)= 6.65$, $p<0.02$, partial $\eta^2=0.26$). Post-hoc comparisons highlighted how responses provided with the left hand were significantly faster in the presence of positive compared to negative distractors ($p<0.01$; means: $M_N=690\pm47$ms, $M_P=660\pm44$ms). The same comparison was not significant for the responses provided with the right hand ($p>0.05$). The result is summarised in Fig. 17. The remaining main factor effects on task RTs were not significant, as well as the other interactions across the three factors ($F<2.8$; $p>0.1$).

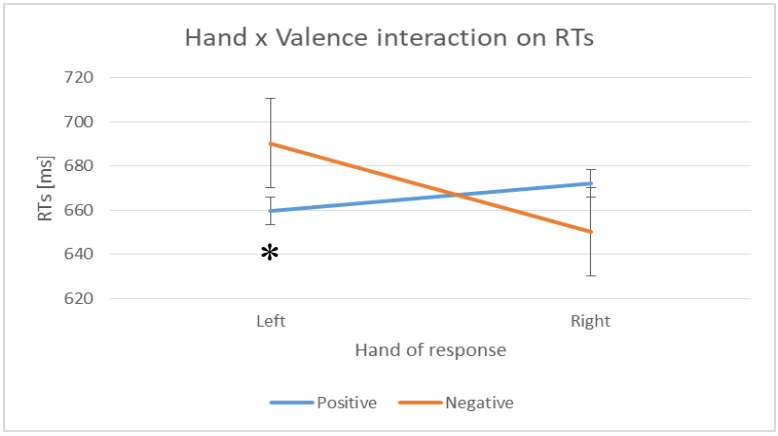


Fig. 17 – The graph displays the significant Hand x Valence interaction on RTs [ms] during the completion of the numerical magnitude comparison task. Blue line represents the responses to trials containing a positive distractor, the orange line the responses to trials containing a negative distractor. RTs are reported on the y-axis. Hand of response is reported on the x-axis.

For the accuracy scores, we found a significant Type x Valence interaction ($F(1,19)= 8.39$, $p<0.01$, partial $\eta^2=0.31$). Post-hoc comparison highlighted how responses to trials containing positive distracting words tended to be significantly more accurate than the ones to trials containing negative words ($p=0.05$; means: $M_P= 98.0\%\pm0.7\%$, $M_N= 96.5\%\pm1.0\%$). The same comparison was not significant for the responses provided to the trials containing positive and negative pictures ($p>0.05$). The results are summarised in Fig. 18. The remaining main factor effects on task accuracy rates were not significant, as well as the other interactions across the three factors ($F<1.5$; $p>0.2$).

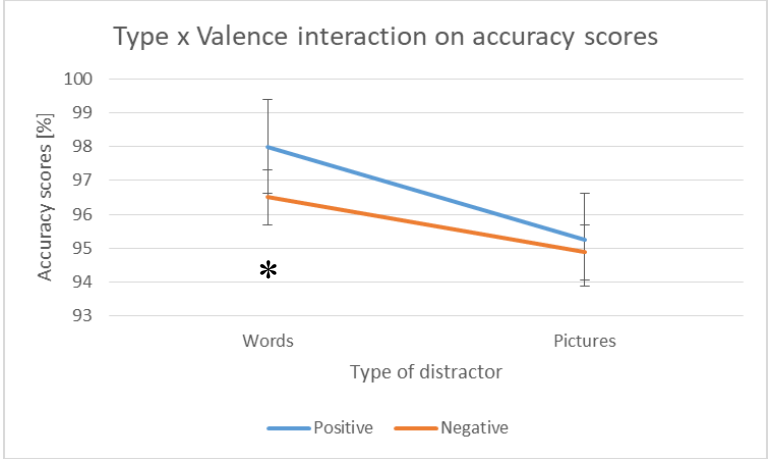


Fig. 18 – The graph displays the significant Type x Valence interaction on accuracy scores [%] during the completion of the numerical magnitude comparison task. Blue line represents the responses to trials containing a positive distractor, the orange line the responses to trials containing a negative distractor. Percentage of task accuracy is reported on the y-axis. The type of distractor presented is reported on the x-axis.

6.4.3. Memory task analysis.

For the new emotional stimuli, there was a significant main effect of Type ($F(1,19)= 33.10$; $p<0.001$, partial $\eta^2=0.67$). Classification of emotional pictures was significantly more accurate than the classification of emotional words ($M_P=83.3\% \pm 3.6\%$; $M_W=53.3\%$

± 4.8%). There was no significant main effect of valence nor a significant interaction between the two factors for the newly displayed stimuli.

For the previously displayed emotional distractors, there was a significant Type x Valence interaction ($F(1,19)=5.69$, $p<0.03$, partial $\eta^2=0.22$). Post-hoc comparison highlighted how negative pictures have been classified significantly better than negative words ($p<0.001$; means: $M_P=86.4\%$ ± 3.4%, $M_W=63.6\%$ ± 4.6%). The results are summarised in Fig. 19. The same comparison between positive words and pictures did not reach statistical significance.

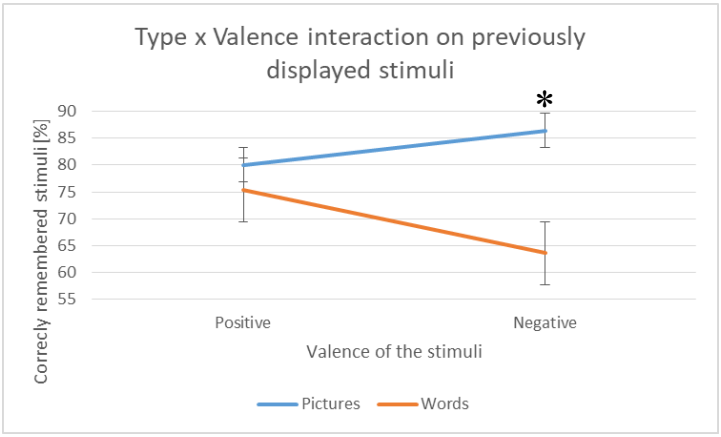


Fig. 19 – The graph displays the significant Type x valence interaction on previously displayed stimuli [%] during the completion of the mnemonic recollection task on the emotional distractors. Blue line represents the responses to trials containing emotional pictures as stimuli, the orange line the responses to trials containing emotional words as stimuli. Percentage of task accuracy is reported on the y-axis. The valence of the stimuli displayed is reported on the x-axis.

6.4.4. Trait-performance correlations.

RTs for the responses provided with the right hand to trials containing positive emotional distracting pictures correlated significantly with the scores of trait Impulsivity (PCC=-0.58, $p<0.01$) provided to the Dickman's Impulsivity Inventory. A scatterplot summarises this result (Fig. 20).

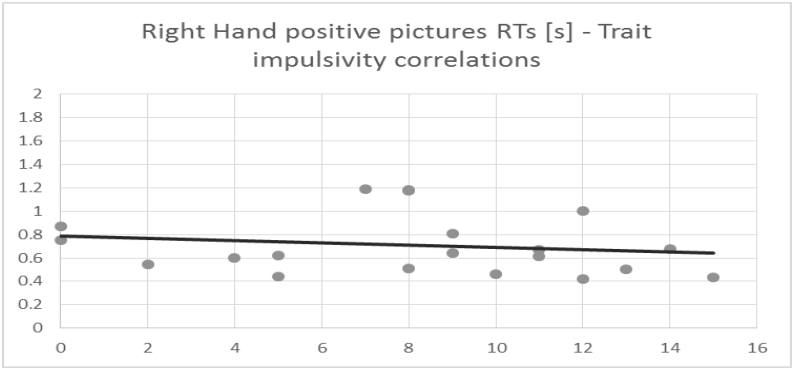


Fig. 20 - Pearson's correlation between task RTs (right hand responses, positive distracting pictures) and Trait Impulsivity scores. Correlation was significant at $p<0.01$ level (PCC=-0.58). The RTs are reported in seconds exclusively for visualization purposes.

To control for the effects that a single outlier can have on the correlation results, the analysis was repeated removing, one at a time, the participants with the highest impulsivity scores. The calculation was repeated twice, removing one outlier at a time. In both cases, the correlation analysis remained significant at $p<0.05$ level.

6.5. Discussion.

In the present study, we aimed to determine the effect that different types of emotional distractors –in particular, positive and negative emotional pictures and words- have on the performance

of a numerical magnitude task. Analysis of task performance highlighted how, in the presence of positive stimuli –independent of the type-, the responses provided with the non-dominant hand were significantly faster than the ones to trials containing a negative distractor. While task accuracy analysis pointed out a first difference between emotional words and pictures, particularly in relation to the valence of emotional words, the following mnemonic recall task highlighted a strong dissimilarity between the two types of stimuli, with pictures classified significantly better than words. This difference was also outlined in the trait-performance correlation analysis, where the degree of advantage brought in by the positive distractors was modulated by personality traits when the distractor was a picture rather than a word.

6.5.1. A partial advantage for positive emotional stimuli.

The analysis of task RTs highlighted a significant Hand x Valence interaction. The responses provided to the task with the non-dominant hand were significantly faster when the task itself was interspersed with positive, compared to the negative, distractors, while for the dominant hand the effect was not significant. This result appears to be independent of the specific type of distractor used. In principle, such finding might appear partially counter-intuitive: according to the body-specificity hypothesis, in fact, positive stimuli should lead to faster responses with the dominant hand and negative ones with the non-dominant hand (Casasanto, 2009). This result has been outlined for emotional stimuli in general; therefore, it is not specific to task-irrelevant affective distractors. However, other studies argued that the abovementioned pattern holds true predominantly for direct valence judgement tasks (see de la Vega, de Filippis, Lachmair,

Dudschig & Kaup, 2012). When emotional stimuli are used as distractors, positive stimuli would bring to a reduction in RTs also in the responses provided with the non-dominant hand (as our findings suggest) solely due to their valence level. Some studies, however, found an advantage for responses to positive (compared to negative) stimuli also in a direct valence judgement with the non-dominant hand (see Milhau, Brouillet & Brouillet, 2015). The aforementioned works support, therefore, our finding that positive distractors, compared to the negative ones, would significantly reduce the time required to complete the associated cognitive task.

A significant reduction brought in by positive distractors, compared to the negatives, is not explicitly manifested for the responses provided with the dominant hand as well. However, in this last case, the reduction of RTs is linked to individual differences in affective dominance. In fact, a significant inverse correlation has been defined between task RTs and self-reported measures associated to BAS dominance. Therefore, as it will be discussed in the following sections, the speed of response for the right hand in the presence of positive distractors undergoes a stronger modulation from individual personality traits, possibly due to the homogeneity in the lateralisation of the brain activity. This would explain the pattern of interaction found in this experiment for the task RTs: positive distractors generated faster responses with the non-dominant hand, without any individual modulation of this advantage. On the dominant hand, instead, this advantage is not expressed as an overall effect, but on a participant-dependent basis.

6.5.2. Task accuracy: words and pictures behave differently.

Two essential results are drawn from the analysis of task accuracy. In the first instance, the advantage brought in by positive distractors in terms of faster RTs does not appear to be compensated by any significant lack of accuracy, making the speed-accuracy trade-off absent in all the three studies illustrated so far. Secondly, it highlights a first, different behaviour of words and pictures while used as emotional distractors. In fact, we found a significant difference, in terms of accuracy rates, between positive and negative words, but not between positive and negative pictures. The result of the pictorial stimuli is in line with our previous two studies where, symmetrically, such a difference was absent. However, with regard to the written stimuli, it appears to be in contrast with other studies present in the literature (Carretié, 2014; Hinojosa et al., 2015; Trauer, Andersen, Kotz & Müller, 2012). These works highlighted how responses to positive and negative emotional words did not lead to significant differences in task performance, neither in terms of RTs nor in terms of accuracy. The authors interpreted this result in terms of salience of the stimuli: since words are considered as weaker distractors than emotional pictures, their ability to influence task performance is judged inferior; hence, it is not possible to establish a significant difference between positive and negative words. It must be noticed, however, how the aforementioned studies did not compare directly the effects of words and pictures but relied solely on the use of words as distractors. Therefore, the alleged difference in salience is fully speculative: the current study, instead, directly compared the two stimuli and found a significantly higher accuracy, for trials containing positive, compared to the negative, words. This result is in agreement with other studies, which found significant performance deterioration in the presence

of negative distracting words, compared to the positives, when employed as task-irrelevant elements (McKenna & Sharma, 1995; Pratto & John, 1991; van Hooff, Dietz, Sharma & Bowman, 2008). The authors interpreted this discrepancy in terms of higher attentional demands deriving from negative stimuli, compared to the positive ones. This increase in attention is possibly due to their higher salience for survival (Ohman, Flykt & Esteves, 2001). According to this interpretation, negative stimuli would require higher sustained attention, making the disentanglement from the distractor and the refocus on the task more effortful. Hence, the higher rate of errors generated by negatively valent words.

Taken together, these results point out several differences in the way emotional words and pictures can affect task performance: however, further investigation is however required to fully categorise these discrepancies.

6.5.3. Memory recall performance: the type of stimulus affects the recognition rates.

If the differences between emotional words and pictures appear limited during the analysis of the RT task parameters (RTs and accuracy), they become more explicit analysing the results of the mnemonic recall task. Two central results deserve attention here: in the first instance, a substantial difference between words and pictures has been defined, in terms of significantly higher accuracy in the classification of both newly shown and previously displayed stimuli. Secondly, considering only the classification of the stimuli previously presented as emotional distractors, the difference in mnemonic recall between words and pictures is particularly pronounced considering negative stimuli.

The higher accuracy for the classification of emotional pictures, compared to the words, in a categorisation task, is a result already present in the past literature (Carr, McCauley, Sperber & Parmelee, 1982; Flaisch et al., 2015; Leclerc & Kensinger, 2011). Again, these works interpreted this significantly different behaviour in terms of higher salience for the pictures in comparison to the words, which in turn should benefit from a more automatic and less effortful processing despite the emotional salience of the content (cf. Augustinova & Ferrand, 2014).

The second result, instead, is consistent with current studies highlighting a negative bias for emotional pictures, compared to words (Storbeck & Watson, 2014; Liu et al, 2009). According to these studies, negative pictures are considered "more negative" than negative words, leading to differences at both stimuli ratings and mnemonic recall levels.

The novelty of the current results lies in two specific aspects of emotional processing. In the first instance, the mnemonic recall has been evaluated on stimuli not explicitly attended, but task-irrelevant. The current work would suggest that the results obtained for studies comparing the effects on working memory of emotional words and pictures could, in principle, be extended to stimuli attended while irrelevant to the task simultaneously completed. Secondly, unlike most of the previously mentioned studies, the comparison between valence levels –and between types of stimuli- has been designed carefully equating the valence normative ratings and, importantly, keeping arousal at a neutral level in order to avoid any influence from the variable. Several studies used emotional stimuli (positive or negative) with a significantly higher arousal than the neutral ones or did not mention the arousal levels for the emotional stimuli used. Since arousal appears to be a strong modulator of mnemonic recall, a

careful manipulation of the variable is essential in the study of these phenomena (cf. Dolcos, LaBar & Cabeza, 2004).

6.5.4. Trait-performance correlations: the effects of trait impulsivity.

Impulsivity appears to be a valid personality trait to mark an association, at the individual level, with task performance when a cognitive task is interspersed with positive emotional pictures. This result is relevant for two reasons in particular.

In the first instance, it complements the finding of the RTs analysis illustrated in the previous sections. While RTs for trials responded to with the left hand are significantly faster in the presence of positive stimuli independent of the type of distractor employed, RTs for the responses with the dominant hand for trials containing positive pictures decrease linearly with the increase of trait impulsivity. Therefore, for the positive distracting pictures, responses with the dominant hand would benefit from a modulatory effect of personality traits, while responses with the non-dominant hand appear to be faster regardless of this modulation.

Secondly, this finding establishes another difference between emotional words and pictures when used as distractors. While, in fact, the effects of pictures on task performance, in terms of RTs, appear to be modulated by individual personality traits related to the BIS/BAS dominance, this modulatory effect is not significant when the distractor is a word. However, this difference is only preliminary and it would require further investigation, particularly considering the lack of reference parameters from the literature concerning the relationship between affective distracting words and personality traits.

6.5.5. Limitations of the current study and future directions.

Although remarkable, several results obtained from the current experiment would need further verification through other studies.

In the first instance, some differences between words and pictures call for further investigation, also considering a possible link between the type of distractors and personality traits.

Due to the different perceptual properties of the stimuli, the study of the differences between stimuli types should consider a more homogeneous type of task in which both words and pictures are used. In this way, it would be possible to split the emotional and perceptual effects of the distractors.

Moreover, in all the studies presented so far, the cognitive task did not hold any emotional connotation: it is questionable whether the aforementioned effects would remain similar or rather be different when the task is switched from a purely cognitive one (as a numerical comparison or Sternberg tasks are) to one that is emotionally salient.

7. Perceptual complexity of emotional distractors affects the responses to emotional targets of opposite valence.

7.1. Abstract.

The perceptual complexity of an emotional stimulus can influence the time needed for its processing and its affective impact on an observer. However, past research on emotional distraction has never analysed the effects of perceptual complexity of affective task-irrelevant stimuli. Moreover, past studies have almost exclusively employed cognitive tasks holding no affective connotations.

In the present study, we aimed to define how task-irrelevant stimuli would influence a valence judgement task interspersed with emotional distractors, particularly in light of the stimuli' complexity. Target elements, valent words or pictures respectively from the Warriner and the NAPS databases, appeared superimposed to a distractor of opposite valence. Twenty-six right-handed young adults completed the aforementioned task, along with a mnemonic recollection task on the emotional distractors presented and several questionnaires to outline their affective dominance (BIS/BAS).

Task reaction times (RTs) and response accuracy provided quantitative information on the influence of the distractors on task performance. Questionnaire scores were correlated with performance data to analyse individual modulations of the distractor-task interplay.

Results highlighted how the presence of low-complexity distractors led to strong differences in the responses to positive and negative targets, the latter being significantly faster and more accurate. Mnemonic recall of affective pictures was significantly higher than the words. An inverse correlation between task RTs and sensitivity to punishment scores was significant only for the emotional pictures but not for the emotional words.

Overall, our results show how the perceptual complexity of emotional distractors can influence the response time to the following target. Moreover, mnemonic recall results suggest a higher affective salience for emotional pictures than emotional words.

7.2. Introduction.

Our previous study hinted at some differences between distracting affective words and pictures, in terms of effects on task performance and mnemonic recall rates. However, we based the choice of the emotional distractors employed solely on their normative valence and arousal ratings. This criterion has been widely exploited in past research and, especially with a tight control over the arousal levels, proved extremely reliable. Our analysis did not take into account two factors potentially relevant in the distractor-task interplay: the perceptual complexity of words and pictures and the emotional salience of the task.

For the emotional pictures, perceptual complexity is expressed as the complexity of the composition (Forsythe, 2009). It has been defined as "the amount of detail or intricacy in the picture" (Snodgrass & Vanderwart, 1980, p. 183). Studies employing object recognition tasks have particularly exploited this factor: the results highlighted how more complex patterns required a longer time for recognition compared to low-complex ones (Brunel & Ninio, 1997;

Rossion & Pourtois, 2004). Previous research on emotional perception also explored the concept of visual complexity in emotionally salient pictures. Gestalt psychologists suggested that one of the first techniques to discriminate the content of a picture is the separation between an object and its background (Elder & Goldberg, 2002). According to the theory, the sharper this contrast (for example, when a single object is depicted), the easier and faster the recognition of the picture. On the contrary, visual scenes without a clear main object (for example, a natural landscape or a crowd) might need longer times to be fully processed. Perceptual organization of the stimuli appears to affect also the brain activity in response to the presentation of emotional stimuli by modulating ERPs (Bradley, Hamby, Löw & Lang, 2007). The authors observed an increase in the ERPs amplitude at both anterior and posterior electrodes sites with the decrease of the complexity of the composition, although this modulation was more evident for positive pictures. It must be noticed, however, how the mentioned study did not control for the arousal levels of the pictures, which could have potentially influenced the results. Moreover, the study only registered passive electrocortical responses while participants viewed the stimuli, without the involvement of any concurrent task. Other studies employing affective distractors as task-irrelevant elements reported instead, at the behavioural level, an absence of differences between low- and high-complex emotional distractors when these influenced the completion of a concomitant task (Müller & Gundlach, 2017). In their experiment, however, the authors only tested the effects of negative distractors, contrasted with a neutral baseline, without any consideration of positive stimuli.

As illustrated here, the relevance of picture composition in emotional processing, particularly in the field of emotional distraction, has not been previously analysed at the behavioural

level. However, due to the findings from Gestalt psychology, this factor could potentially affect the speed an emotional distractor is processed and, consequently, the effects it has on the completion of a concomitant task.

For the written stimuli, the concept of perceptual complexity has been expressed as the familiarity of the words. Past research highlighted how more familiar stimuli received faster recognition rates but were recalled with lower confidence compared to less familiar stimuli, due to the higher individual risk of confounds perceived (Henson, Rugg, Shallice & Dolan, 2000; Henson, Rugg, Shallice, Josephs & Dolan, 1999). Kuchinke and colleagues (2006) extended these findings to emotionally salient stimuli, determining in addition higher accuracy rates for positive, compared to negative words, in the recognition of new and old stimuli presented during a working memory task. In this case, emotional words were presented as explicit stimuli, therefore mnemonic recall analysis did not take into account a condition of learning derived from the exposure to task-irrelevant emotional distractors. For these reasons, the familiarity of emotional words used as task-irrelevant elements could potentially play a similar role as the complexity of composition for emotional pictures.

Past research has used direct valence judgement tasks to analyse the effects of emotional distractors when a concomitant task has a relevant emotional connotation. Madill and Murray (2017) for example, presented a series of emotional pictures flanked by two emotional distractors: according to their results, positive targets received faster responses regardless of the valence of the distractor, therefore excluding any effect from incongruence between the valence of targets and distractors. However, Lichtenstein-Vidne and colleagues (2007) had previously pointed out how irrelevant information presented at the centre of attention would receive different processing with respect to information that

flanks the central, salient one. Therefore, presentation of the distractor on the side of the relevant stimuli might have influenced the results of the study by Madill and Murray. In either case, however, the complexity of the stimuli has not been considered as a parameter influencing the choice of the affective material, nor analysed in relation to task performance.

From this theoretical framework, and taking into account the results obtained from the previous studies, we set up a fourth experiment aiming to define the effects that emotional distracting words and pictures can have on the completion of a valence judgement task. This was studied particularly in light of the perceptual complexity of the distractors and of the possible influence of affective incongruence between targets and distractors. Both the distractor and the target within each trial were presented centrally to ensure the full processing of the two elements; moreover, in order to guarantee full comparison across studies, the emotional distractors selected in this experiment were identical to the previous study. From the results of past research, we hypothesised a significant difference between low- and high-complex distractors in terms of effects on task completion. The low-complex ones are hypothesized to be faster to process, therefore their disruptive effect on task performance is expected to be stronger in terms of higher RTs and lower accuracy rates. Moreover, we predicted a difference between words and pictures not only in terms of effects on task performance but also in the mnemonic recall rates of the stimuli.

7.3. Materials and methods.

7.3.1. Participants.

Twenty-six right-handed young adults (age: 24.6 ± 4.2 years; range: 18-34), 13 of them females, voluntarily agreed to take part in the study. Due to the presence of emotional words as distractors within the task, we selected only native English speakers, to ensure the full comprehension of the stimuli used. Their laterality index was established using the Edinburgh handedness inventory (Oldfield, 1971): the mean laterality index was 93.5 ± 9.0; ranging between +75 and +100. The study received approval from the local Ethics Committee and, in accordance with the declaration of Helsinki, each participant gave informed written consent to participate before the beginning of the experiment. They received an inconvenience allowance at the end of the session.

7.3.2. Task and procedure.

At the beginning of the experimental session, participants completed a series of questionnaires to use as a self-reported measure of emotionally relevant personality traits. In particular, the questionnaires administered included: Carver-White questionnaire (Carver & White, 1994); Sensitivity to Reward/Punishment Questionnaire SPSRQ-35 (Torrubia, Ávila, Moltó & Caseras, 2001); Dickman's Impulsivity Inventory DII (Dickman, 1990); State-Trait Anxiety Inventory STAI-Y (Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983). They were used to establish, respectively, the degree of dominance for the Behavioural Activation/Inhibition Systems; the sensitivity to reward- and punishment-eliciting stimuli (which is an alternative way to establish BIS/BAS dominance), the level of trait impulsivity and the level of trait anxiety. The last two, according to Gray

(1981), are the "operative traits" that modulate the Activation and Inhibition systems respectively and can be taken as measures of the BIS/BAS individual levels.

Immediately after, they completed a valence judgement task interspersed with emotional distractors. As illustrated in Fig. 21, each trial started with a fixation cross displayed for 1000ms; then an emotional distractor appeared on the screen for 500ms followed by an emotional target overlapping the distractor for 500ms. During the presentation of the targets, the distractors remained on the screen. Trials ended with an inter-trial interval of variable duration between 2000 and 4000ms after the simultaneous offset of targets and distractors (not shown in the figure).An example of a trial containing words as stimuli is displayed in Fig. 22.

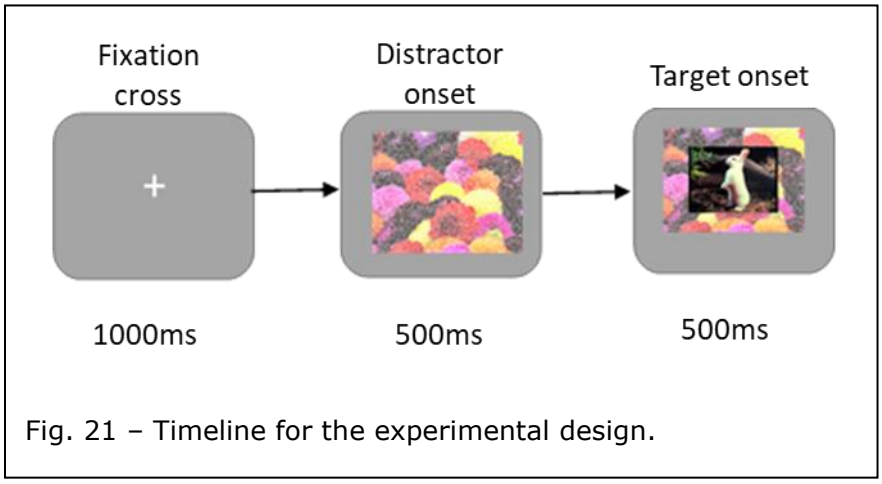


Fig. 21 – Timeline for the experimental design.



Fig. 22 – Example of a trial containing affective words, as it appeared during the presentation seen by the participants.

Size of the targets was reduced and their opacity lowered to ensure a partial vision of the distractor during the presentation of the target but allowing, at the same time, a full detection of the target. The optimal values for all the measures (visual parameters and presentation timing) have been obtained through a series of pilot studies that preceded the current experiment (results of the pilot studies are omitted). Opacity for the targets was kept at 85% of the original value; opacity of the distractor at 50% of the original value.

Participants were instructed to provide a response to each trial by pressing a key on an Apple computer keyboard, using only one hand per experimental block according to the instructions on the screen. Using the index and middle fingers, they were asked to respond by pressing two different keys if the target stimulus overlapping the distractor was positive or negative. Participants were asked to respond to each trial in the fastest and most accurate way possible. The valence of targets and distractors was opposite for all trials (i.e. a positive target always overlapped a negative distractor and vice versa). The combination of keys was different for the two hands to ensure that no habituation effect influenced the responses. The onset of the target stimulus on the pc screen marked the beginning of the time segment used to

calculate RTs. Each participant completed four blocks of trials; two of the blocks required a response using the right hand; two required a left-hand response. For each hand, one of the two blocks contained emotional pictures as targets and distractors; the other block contained instead emotional words. Each block was composed of 30 trials; half of the trials contained a positive target, the remaining half a negative one. Before the actual start of each block, participants completed a short (5 trials) practice block to get familiar with the structure of the trials, the pace of the presentation and the keys to be pressed to provide their responses.

At the end of the four blocks, participants viewed a set of 30 emotional pictures and 30 emotional words, evenly split into positive and negative. They were asked to rate the pleasantness of each element on a 9-point scale; subsequently, they stated whether the stimulus had been presented during the RT task or it was being displayed for the first time. Stimuli appeared for 3000ms and were preceded by a fixation cross, displayed for 2000ms, appearing on the screen after the responses to the antecedent trial were provided. Participants were unaware of the presence of this last block although were told, during the experiment, not to focus only on the cognitive task but to pay attention to the distractors too.

7.3.3. Stimuli used.

For the valence judgement task, we employed 48 positive and 48 negative pictures from the NAPS database and 48 positive and 48 negative words from the Warriner database as emotional stimuli. Half of the elements have been used as targets, the other half as distractors. All the ones employed as distractors in the current task have been already used as distractors in the previous study, in

order to allow a full comparison for the results across the two experiments with regard to the effects of the distractors. The stimuli used as targets were selected on the same grounds as the distractors. Based on the normative ratings provided in the databases, both using the same criteria, scales, validation methods and internal consistency of the IAPS, we picked stimuli rated between 1 and 3 on the arousal scale; the positives had a valence rating between 7 and 9; the negative ones between 1 and 3. For the pictures, within each valence level, we balanced the choice in terms of content (people, objects, animals, human faces and natural scenes) and physical properties. For the words, we selected only verbs with abstract content and a total length between three and eight letters (i.e. love, hate). We excluded words strongly related to motor actions (i.e. 'push', 'pull') since they could potentially alter the RTs between the dominant and non-dominant hand (Dreyer et al., 2015; Pulvermüller, 2013; Pulvermüller, Moseley, Egorova, Shebani & Boulenger, 2014). A word has been categorized as abstract if it "describes internal states of the body", in contrast to action words, which are "semantically related to actions typically performed by moving different parts of the body (such as "talk" and "walk"), which activate body-part–specific representations in sensorimotor cortex" (Moseley, Carota, Hauk, Mohr & Pulvermuller, 2012, p. 1635). Action words can have also positive and negative valence (for example, "hug" Vs "stab"). Therefore, for the purpose of a valence judgement task, both categories of words could have been employed with equally valid choice criteria since both fall under the definition of "emotional words". However, their link with motor execution is tighter and can lead to differences in task performance between the dominant and non-dominant hand due to the mapping, planning and execution of the action expressed by the word. For this reason, we decided to employ exclusively abstract words.

The criterion of complexity for the composition of the pictures was equated with the criterion of familiarity of the words: high-complexity pictures were matched with less familiar words, while low-complexity pictures were matched with words that are more familiar. Classification of pictures was based on visual inspection of the composition, under the hypothesis of a clear object background Vs scene composition for the two levels of complexity. Words familiarity has been established following the norms provided by Stadthagen-Gonzalez and Davis (2006).

Within the blocks containing emotional pictures, the target matched with each distractor differed in terms of the content of the pictures but was fully randomised in terms of complexity of the two stimuli. For the trials containing emotional words, the length of the distractors was always superior to the targets, in order to allow a full overlap of the target with the distractor itself.

In the memory task that followed the RT task, we selected 30 positive and 30 negative stimuli, half of which were pictures and half words per valence level, 67% of which have been already presented during the RT task and the remaining 33% were new to the participants. Across the previously displayed stimuli, half of them were targets and the remaining half have been presented as distractors. The new stimuli, both words and pictures, were selected on the same criteria for valence and arousal; the previously seen distractors were instead selected randomly within the pool of stimuli used in the RT task.

7.3.4. Statistical analysis.

For the Carver-White questionnaire, overall BIS/BAS dominance was established by the means of t-tests on the average scores for the two Activation and Inhibition scales. We did not use overall scores due to the different number of items that each scale

presents within the questionnaire. For the SPSRQ, sensitivity to reward/punishment has been calculated as the overall score of the two subscales due to the homogeneity in the number of elements present in the two. The dominance of Reward-Punishment system was established by the means of t-tests on the overall score of the SP and SR subscales.

The degree of trait impulsivity and anxiety from the DII and STAI-Y questionnaires have been calculated as the overall score of each scale.

With regard to the behavioural data, the RTs for the cognitive task have been analysed by means of 2 x 2 x 2 ANOVA (Type: Picture Vs Word; Distractor Complexity: Low Vs High; Target Valence: Negative Vs Positive). The same statistical test structure has been used to assess task accuracy. In both cases, responses with the left and right hands have been averaged across conditions. Due to the simultaneous presence of these three factors, and due to the results obtained in our previous studies, we decided to direct our attention only on the aforementioned parameters, not including the hand of response as a fourth factor. Our previous analyses on the hand of response factor were inconsistent and, possibly, not related exclusively to the presence of emotional distractors. Instead, we preferred to focus on the analysis of three factors that, potentially, would provide the strongest information on the effects of distracting stimuli on task performance. By averaging the responses provided with the left and right hand, we also added robustness to effects of the three selected factors, by doubling the numbers of the trials belonging to each factor group. We judged this being the optimal design to study the effects we are interested in.

For the memory task, performance was analysed by means of 2 x 2 ANOVA (Type: Picture Vs Word; Valence: Negative Vs Positive).

Two separate analyses were conducted for the new stimuli and the previously displayed distractors during the RT task.

Trait-performance correlations were calculated as Pearson's Correlation Coefficient between RTs in response to specific task conditions and individual scores for the BIS/BAS dominance, trait impulsivity and trait anxiety scales. In particular, for the trials containing a positive distractor, RTs for both low and high complexity distractors have been correlated with BAS dominance, trait impulsivity and sensitivity to reward questionnaires scores. For the trials containing a negative distractor, RTs for both low and high complexity distractors have been correlated with BIS dominance, trait anxiety and sensitivity to punishment questionnaires scores.

The statistical threshold was set at $p < 0.05$ and we applied Bonferroni corrections for multiple comparisons where appropriate. Throughout the Results section, mean scores ± SE are reported.

7.3.5. Data pre-processing.

For the statistical analysis, we excluded the trials that received an incorrect response (errors). We marked as errors also the trials that received a double response, either if the first response was wrong and the second correct, or vice versa. Moreover, the trials that did not receive a response (missed trials) were considered as errors and therefore included in the accuracy, but not in the RTs, analysis.

After this first step and before the statistical analysis, we applied an outlier exclusion correction on individual trials on the grounds of the individual speed of response. In particular, within each participant, we calculated the Means (Ms) and Standard Deviations (SDs) for the trials containing either pictures or words and excluded from the analysis all the trials falling outside the range of

M±2SDs within each type level, as considered significantly anticipated or delayed responses. The trials excluded were not considered for the RTs nor the accuracy analyses. The remaining trials were used for the statistical analysis outlined in the previous subsection. Overall, in the current study, the rejection rate was inferior to 5% of the total trials; the highest rejection rate in a participant was 8.4%.

7.4. Results.

7.4.1. Behavioural dominance.

For the Carver-White questionnaire, no significant difference has been found between the average BAS and average BIS scores. For the SPSRQ questionnaire, no significant differences have been found between the SP and SR scales. In both tests, level of significance was $p>0.4$. Therefore, the behavioural dominance of the participants was heterogeneous and not driven towards one of the two systems.

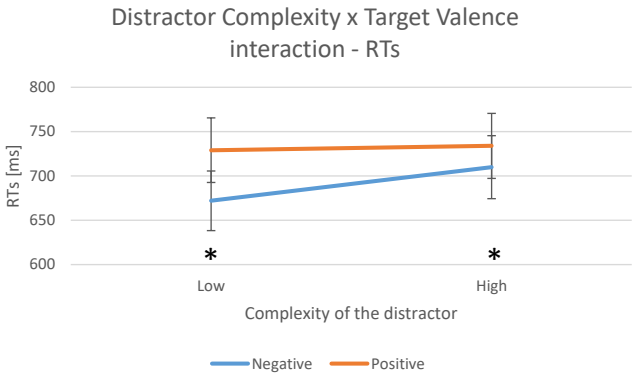
7.4.2. RT task analysis.

For the RTs, there was a significant Type x Target Valence interaction ($F(1,25)=5.02$, $p<0.05$, partial $\eta^2=0.17$). Post-hoc comparisons highlighted how trials containing negative pictures as targets received significantly faster responses compared to trials containing positive pictures as targets ($p=0.001$; means: $M_N=695\pm22$ms; $M_P=753\pm22$ms). The same pairwise comparison between trials containing a positive or a negative word as the target did not reach the significance threshold level.

There was also a significant Distractor Complexity x Target Valence interaction ($F(1.25)=6.39$, $p<0.05$, partial $\eta^2=0.20$). Post-hoc

comparisons highlighted how negative targets preceded by a low-complexity distractor received significantly faster responses compared to positive targets preceded by a low-complexity distractor ($p<0.02$; means: $M_N=672\pm20$ms; $M_P=729\pm22$ms). Moreover, negative targets preceded by a high-complexity distractor received significantly faster responses compared to positive targets preceded by a high-complexity positive distractor ($p<0.05$; means: $M_N=710\pm26$ms; $M_P=734\pm23$ms). Response time to negative targets was significantly lower than to the positive targets, in the presence of both low and high complex distractors preceding the targets. The difference was independent of the type of stimuli employed. Both interactions are illustrated in Fig. 23.

The remaining interactions between the analysed factors did not reach significance level ($F<1.8$; $p>0.2$).



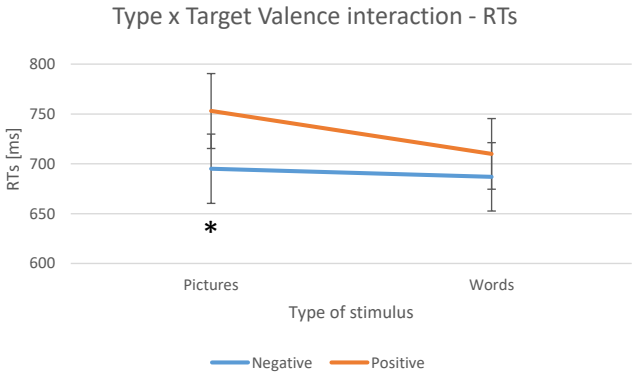


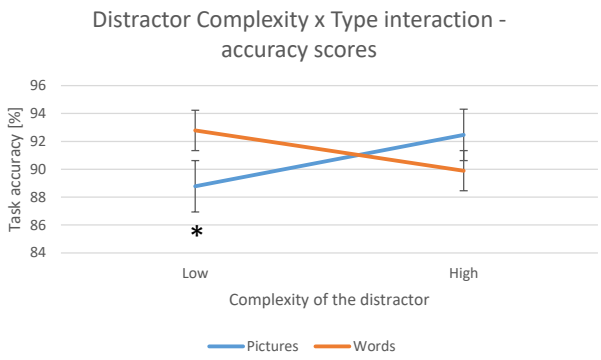
Fig. 23 – The graph displays the significant Distractor Complexity x Target Valence (on top) and the Type x Target Valence (at the bottom) interactions on RTs [ms]. Top graph: distractor complexity on the x-axis. Bottom graph: stimulus type on the x-axis. Both graphs: RTs on the y-axis. Blue line: responses to trials containing a negative distractor; orange lines: responses to trials containing a positive distractor.

For the accuracy scores, there was a significant Type x Distractor Complexity interaction ($F(1,25)=10.61$, $p<0.005$, partial $\eta^2=0.3$). Post-hoc comparison highlighted how, in the presence of low-complexity distractors, words trials received significantly more accurate responses compared to pictures trials ($p<0.05$; means: $M_W=92.7\%\pm1.3\%$; $M_P=88.7\%\pm1.6\%$). The same comparison between high-complexity words and pictures did not reach significance threshold level. Participants provided significantly more accurate responses to written, compared to the pictorial stimuli, when the preceding distractor had a low level of perceptual

complexity. This effect was independent of the valence of the targets and the distractors employed.

There was also a significant Distractor Complexity x Target Valence interaction ($F(1,25)=17.70$, $p<0.001$, partial $\eta^2=0.40$). Post-hoc comparisons highlighted how, in the presence of low-complexity distractors, negative targets received significantly more accurate responses than positive targets ($p<0.001$; means: $M_N=94.01\%\pm1.4\%$; $M_P=87.50\%\pm1.6\%$). The same comparison in the presence of high-complexity distractors did not reach statistical significance. Both interactions are illustrated in Fig. 24.

The remaining interactions between the analysed factors did not reach significance level ($F<2.10$; $p>0.15$).



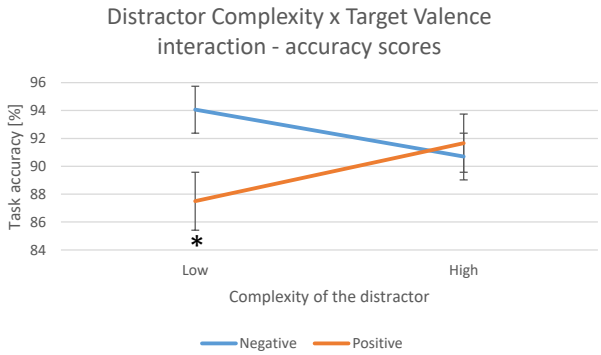


Fig. 24 – The graph displays the significant Complexity x Type (on top) and the Complexity x Valence (at the bottom) interactions on accuracy scores [%].
Top graph: the blue line: trials containing pictures as stimuli; orange line: trials containing words as stimuli. Bottom graph: blue line: responses to trials containing a negative distractor; orange lines the responses to trials containing a negative distractor. Percentage of correct responses are reported on the y-axis in both graphs. Complexity of the distractor is reported on the x-axis.

7.4.3. Memory task analysis.

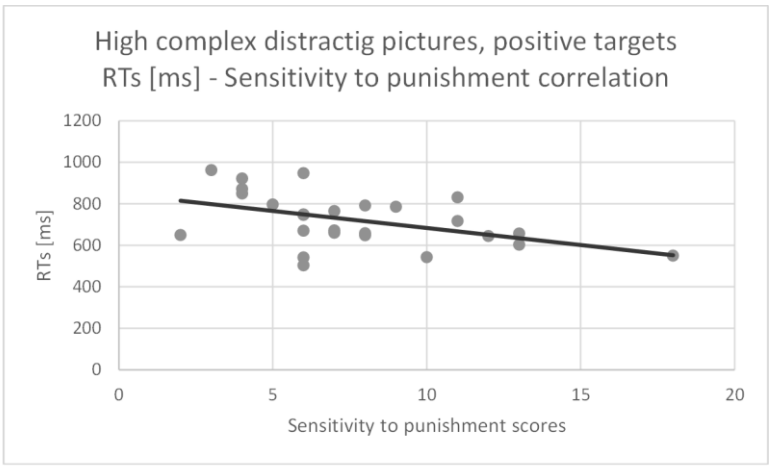
For the newly displayed emotional stimuli, there was a significant main effect of Type ($F(1,25)=19.42$; $p<0.001$, partial $\eta^2=0.44$). Classification of emotional pictures was significantly more accurate than the classification of emotional words ($M_P=83.3\%\pm3.6\%$; $M_W=75.4\%\pm2.8\%$). There was no significant main effect of valence nor a significant interaction between the two factors ($p>0.1$).

For the previously displayed emotional distractors, there was a significant main effect of Type ($F(1,25)=7.94$, $p<0.01$, partial $\eta^2=0.24$). Classification of emotional pictures was significantly

more accurate than the classification of emotional words (M_P=72.1%±2.2%; M_W=63.4%±2.3%). There was no significant main effect of valence nor a significant interaction between the two factors ($p>0.1$).

7.4.4. Trait-performance correlations.

Reaction Times in response to positive target pictures correlated with sensitivity to punishment scores in the presence of both high-complex (PCC=-0.49, $p<0.02$) (Fig.25, top) and low-complex (PCC=-0.47, $p<0.02$) (Fig. 25, bottom) distractors. Participants with higher scores in the sensitivity to punishment scale benefitted more from the presence of a negative distractor, followed by a positive target, in the performance of the task: the higher levels of the trait led to progressively faster responses to the judgement of the valence of a positive target. This result is independent of the complexity of the distractor displayed since the correlation was found significant for both low- and high-complex negative distractors preceding the positive targets.



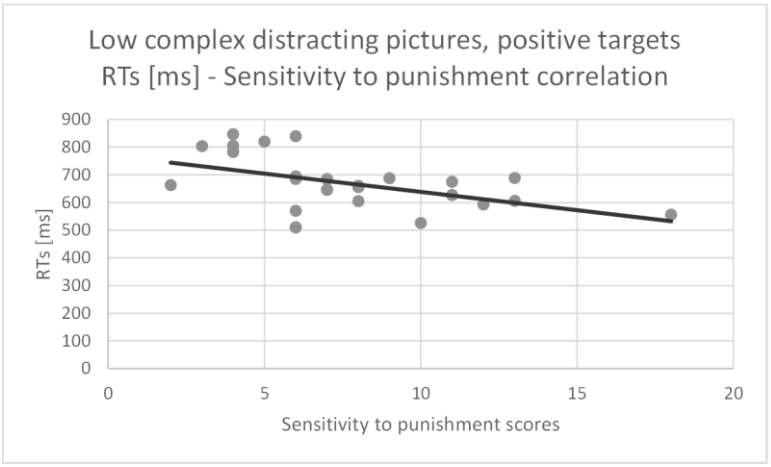


Fig. 25 – Pearson's correlation between task RTs (responses to trials containing high-complex distracting pictures and positive targets) and sensitivity to punishment scores (top); Pearson's correlation between task RTs (responses to trials containing low-complex distracting pictures and positive targets) and sensitivity to punishment scores (bottom).

To control for the effects that a single outlier can have on the correlation analysis, both analyses were repeated removing the participant with the highest sensitivity to punishment scores. For all the repeated analyses, Bonferroni correction for multiple comparisons has been applied. In all cases, the correlation analysis remained significant at $p<0.05$ level.

The symmetrical analysis, operated on trials containing emotional words, did not instead reach the significance threshold. All the

remaining correlations run between personality traits and task performance did not reach statistical significance.

7.5. Discussion.

In this study, we analysed the effects of written and pictorial emotional distractors on the performance of a valence judgement task, particularly in light of the perceptual complexity of distracting stimuli.

The perceptual complexity of the distractors affected the response time to the task, independent of the type of stimulus employed.

The subsequent mnemonic recall task highlighted, instead, a significant difference in the recall rates between words and pictures.

Finally, responses to trials containing emotional pictures were modulated more consistently by individual personality traits than responses to trials containing emotional words.

7.5.1. Task performance: a significant difference between positive and negative stimuli.

The first salient result of the current study is a significantly faster response provided by the participants to negative targets, compared to the positive ones, independent of the level of complexity of the distractor preceding the targets. Due to the structure of each trial, this result can be dually interpreted as an advantage in direct response to negative targets and an advantage brought in by positive distractors. The latter interpretation would be in line with the previous studies we ran, which already outlined how positive distractors can lead to the reduction of RTs in task performance. Past research (Houwer & Hermans, 1994; Ohman, Flykt & Esteves, 2001; Ohman, Lundqvist & Esteves, 2001;

Vuilleumier, 2005), however, pointed out how participants detected negative targets more rapidly than other emotionally salient stimuli, independent of the valence of emotional distractors simultaneously presented. With these considerations, both elements (a positive distractor and a negative target) presented concurrently within the same trial could equally be responsible for the described effects on task RTs. A change in the design, using the same stimuli but congruently matched with respect to valence, would possibly help to clarify which of the two components (if any) leads this significant difference across responses between positive and negative targets. In fact, significantly faster responses to negative targets in a congruent condition would suggest the ascription of the current effect to the valence of the targets; on the other hand, significantly faster responses to positive stimuli would underline the decisive role of the distractors in driving task performance. Eventually, an absence of any significant effect due to valence would hint at the fact that, possibly, it is the concomitant presence of positive distractors and negative targets to drive the reduction of RTs in the incongruent condition. This, of course, under the condition that the stimuli administered would be identical in the two studies.

The second relevant result is that, within an emotionally salient task, a difference between the types of stimuli is strongly expressed. While no significant differences arose between responses to positive and negative target words, negative target pictures received significantly faster responses than the positive counterpart did. This result is in line with previous studies that highlighted how, in the presence of a concomitant emotionally salient task, no differences are highlighted between valence levels of emotional distracting words presented during the task completion (Jackson, Linden & Raymond, 2012). Similarly, other works pointed out how the presence of an emotional distractor

leads to significant differences in the evaluation of subsequently presented positive and negative stimuli (Palumbo, Ogden, Makin & Bertamini, 2014). Therefore, the present study suggests that valence alone might not be sufficient to explain the effects of emotional distractors on task performance: different types of stimuli, as written or pictorial, can lead to different responses to subsequently presented positive or negative targets.

7.5.2. The role of distractors' features: complexity of the pictures and familiarity of the words affect task performance.

The complexity of the emotional distractors, a simple object-background composition for the pictures and higher familiarity for the words, significantly affected the responses to the associated cognitive task. The effects of complexity on the perception of emotionally salient stimuli have been previously analysed by studies manipulating this factor in the context of a valence judgement task on emotional words and pictures (Schlochtermeier et al., 2013). Although the authors did not highlight a difference in terms of behavioural measures, high-complexity stimuli generated stronger brain activity, registered via fMRI scansions, that is interpreted in terms of more effortful processing of these stimuli. However, this study presented pictograms as low-complex stimuli rather than full pictures, with a different (and perhaps questionable) choice criterion for picture complexity. In addition, our study manipulated stimulus complexity at the distractor –and not the target- level, to our knowledge for the very first time. Here, we suggest how perceptual complexity of an emotional distractor is a parameter that actively influences task performance and, importantly, manifests its effects even at the behavioural level. For this reason, it should be carefully controlled in the study

of emotional distraction, just as it happens with the dimensions of valence and arousal. Moreover, other authors reported how negative distractors, when directed at the centre of attention of the participant completing a concomitant task, led to significantly higher interference than the positive counterpart did (Okon-Singer, Tzelgov & Henik, 2007). The authors interpreted the result as a difference in the processing of positive and negative emotional distractors, the latter being automatic, not requiring conscious monitoring, being an expression of a primitive survival response. The different salience of low-complex object-background composition would, therefore, facilitate this processing, leading to a stronger effect of the distractor on task completion.

7.5.3. Memory recall performance: a higher salience of emotional pictures.

Despite the different salience of the proposed cognitive task, in terms of the emotional connotation of the stimuli, results in the mnemonic recollection task did not present any difference compared to our previous studies. Again, emotional pictures received a significantly better classification, independent of the fact that they have been previously presented during the RT task or have been seen by the participants for the first time. Our results are in agreement with previous studies which have also analysed the effects on memory of emotional words and pictures in the context of a valence judgement task, highlighting a superior accuracy for pictorial than written stimuli (Azizian, Watson, Parvaz & Squires, 2006; Seifert, 1997). Authors interpreted the finding in terms of privileged access, for the pictures, to semantic memory. This factor, along with a proposed higher salience for emotional pictures than words, would explain the higher recollection rate for

the pictorial stimuli (Flaisch et al., 2015; Grady, Mcintosh, Rajah & Craik, 1998).

7.5.4. Trait-performance correlations: a significant association only for emotional pictures.

Confirming the results obtained in the previous study, the findings of the present work suggest that personality traits would modulate, at the individual level, the effects of emotional pictures more robustly than the ones of emotional words. However, the pattern of modulation highlighted in the results is particular and, in some ways, extremely interesting. In fact, past research underlined a correlation between BAS scores with positive stimuli and BIS scores with negative stimuli, at both behavioural (stimuli rating) and brain activity (signal amplitude) levels (Balconi & Vanutelli, 2016). In our study, RTs in responses to positive target pictures linearly decreased with increasing levels of sensitivity to punishment scores, a measure of trait behavioural inhibition. This can appear counterintuitive at the beginning: however, it must be noticed how any positive target picture was preceded by a negative distracting one, and how the linear decrease of RTs as a function of BIS dominance was significant only for the negative distractors and not for the negative targets. Therefore, the novel result proposed by the current research is that the modulatory effect of personality traits is expressed at the level of the distractor even when the task has emotionally salient connotations; moreover, this effect is independent of the perceptual complexity of the scene depicted in the distractor. In addition to this, the correlation analysis stresses again the accent on the existing differences between the two types of stimuli employed. The absence of modulation for the words can be interpreted in terms of higher levels of semantic processing required, rather than an immediate perception of the affective content, that would rule out

any modulatory effect from individual personality traits in favour of a more homogeneous processing across participants with different behavioural dominance (Hinojosa, Carretié, Valcárcel, Méndez-Bértolo & Pozo, 2009). Therefore, having pictorial stimuli privileged access to emotional information, they would generate greater activation of the individual behavioural systems (Glaser, 1992; Paivio, 1991).

7.5.5. Limitations of the current study and future directions.

The present study allowed outlining further differences between emotional words and pictures, in the context of emotional distraction, particularly in light of the perceptual complexity of the stimuli.

However, only an incongruent condition, in terms of the valence of the distractor and the associated target, has been analysed. Future research would need to take into account the effects that a congruent distractor-target matching could generate, and if the effects of incongruence between the two elements are similar or heterogeneous compared to a congruent situation, where the distractor would play the role of an active cue for the task response rather than generating a situation of affective conflict.

Moreover, a congruent distractor-target design would help clarifying if the type of stimulus is relevant in the emotion-cognition interplay (i.e. if the effects of a cue are similar or different for words and pictures) and if the complexity of the distractor would influence the response to a subsequent target homogeneous in terms of stimulus type and level of valence.

Finally, it will be assessed whether such a change in the design would affect the mnemonic recall of the two types of stimuli and the modulation of the task response by individual personality traits of behavioural dominance.

8. Perceptual complexity of emotional distractors affects the responses to emotional targets of congruent valence.

8.1. Abstract.

Past studies on emotional distraction employing emotionally salient tasks mainly considered an incongruent valence relationship between task targets and distractors. Analyses of valence congruency have been seldom reported. Moreover, the perceptual complexity of the distractors has not been taken into account as a relevant parameter to assess their influence on task performance.

The current work aimed to analyse the impact of affective distractors on the performance of an emotionally salient task, in which the valence of the distracting and the target elements was always congruent. Twenty-nine right-handed young adults performed a valence judgement task in which target stimuli, affective words or pictures from the Warriner and NAPS databases respectively, appeared superimposed to a distractor of congruent valence. Along with the aforementioned task, they completed a mnemonic recollection task on the emotional stimuli presented and several questionnaires to outline their affective dominance (BIS/BAS).

Task reaction times (RTs) and response accuracy provided quantitative information on the interference of the distractors on task performance. Questionnaires scores were correlated with performance data to analyse individual modulations of the distractor-task interplay.

The analysis showed significantly faster and more accurate responses to trials containing affective words than pictures as stimuli. Low-complex distracting pictures generated significantly

faster responses to positive than negative targets. The mnemonic recall of displayed emotional stimuli showed a pattern of higher accuracy for positive words and negative pictures, while previously unseen pictures received significantly better classification than words.

Overall, this study outlined strong differences between words and pictures in task completion, the former receiving significantly faster and more accurate responses.

8.2. Introduction.

While completing a cognitive task, an incongruence between two stimuli presented or between two features of the same stimulus can affect the participant's performance on the task itself. A classic example from literature is the Stroop task, where a word naming a colour is presented in different font colours (MacLeod, 1991; Stroop, 1935). The conflict arises when the word and the font colour are incongruent (for example, the word "blue" presented in green font). In this case, the discrepancy involves the physical and semantic representations of the written stimulus. When this conflict is removed, in a situation of relative congruence between the two elements (for example, the word "blue" presented in blue font), RTs in response to either the written word or the font colour (recognition task) are significantly lower compared to a condition of incongruence.

Research in the field of emotional processing has exploited such concept of interference in what has been defined the "emotional Stroop task". In this case, naming the font colour of emotionally salient words, compared to neutral, creates response delays similar to the ones generated in the classic colour-word incongruence (Ben-Haim et al., 2016; Compton et al., 2003). However, in the aforementioned works, no difference between

positive and negative stimuli has been outlined, since they only accounted for the emotional Vs neutral contrast.

Other studies moved forward and designed a Stroop-like task using emotional words superimposed to pictures, asking the participants to express a judgement on the valence of either type of stimulus (Beall & Herbert, 2008; Ovaysikia, Tahir, Chan & DeSouza, 2011; Rosinski, Golinkoff & Kukish, 1975). Findings consistently determined a significant effect of the valence congruence between the two stimuli (target and distractor) on the time needed to provide a response, decreasing in comparison to an incongruent condition. They also reported stronger disruptive effects (longer RTs and lower accuracy rates) when the pictorial stimuli were used as distractors for a word recognition task than the opposite condition, when the words were used as distractors.

Analysing one single stimulus domain, Bayliss and colleagues (2010) designed an emotional target localization task interspersed with emotional faces as cues. When the emotion depicted in the distracting face matched the valence of the emotional target, RTs decreased significantly in comparison to the incongruent condition.

Therefore, the presence of a valence-related congruency between a distractor and a task target can significantly affect the performance on an emotionally salient task compared to a situation of relative incongruence. This effect has been linked, at the behavioural level, to the activity of the Inhibition system. According to current studies, the BIS would not be activated by withdrawing-like stimuli; rather, it would act as a conflict-detection system (Berkman, Lieberman & Gable, 2009). In this view, a congruence in valence between targets and distractors, and therefore the elimination of the affective mismatch, would help to clarify whether the inhibition system is in any case activated by negative inputs or rather serves predominantly as a conflict detector. In the first hypothesis, a higher interference from

negative distractors, compared to the positive ones, would still be present, possibly increasing with higher BIS dominance. In the second case, instead, this difference should in principle be reduced, if not absent.

From the theoretical background illustrated, it noticeably appears how several aspects of the effects of congruent affective distractors on the completion of a cognitive task still need to be clarified. In the first instance, and to the best of our knowledge, past studies never compared the effects of affective distracting and target words and pictures, congruent in valence, without mixing the two types of stimuli within the same trial. This separation would be essential to define the effects of emotional congruence in each stimulus domain. Moreover, none of these works considered the relevance of perceptual complexity in the analysis of the distracting stimuli. We widely described the relevance of this parameter in the previous chapter of this thesis, therefore its inclusion in the analysis of affective congruence might be essential to delineate the effects of emotional distractors on task performance. Finally, past research never included the analysis of individual differences, in terms of behavioural dominance, as a possible modulator of task performance in the presence of affective distracting elements.

To fill this theoretical gap, we set up a behavioural experiment aiming to test the effects of congruent cues in a valence judgement task. This was studied particularly in light of the perceptual properties of the distractors employed (familiarity of the words and composition of the pictures). We hypothesised a significant difference between low- and high-complex distractors in task performance: with the low-complex ones being faster to process, their disruptive effect is expected to be stronger. Moreover, we predicted a difference between words and pictures not only in terms of effects on task performance but also in the

mnemonic recall rates of the stimuli. In addition, we predicted a difference between positive and negative stimuli, providing a facilitation in the response to positive stimuli preceded by congruent cues highlighted in previous research (Wisco, Treat & Hollingworth, 2012).

8.3. Materials and methods.

8.3.1. Participants.

Twenty-nine right-handed young adults (age: 23.8 ± 3.8 years; range: 18-32), 16 of them females, voluntarily agreed to take part in the study. Due to the presence of emotional words as distractors within the task, we selected only native English speakers, to ensure the full comprehension of the stimuli used. Their laterality index was established using the Edinburgh handedness inventory (Oldfield, 1971): the mean laterality index was 93.8 ± 8.8; ranging between +75 and +100. The study received approval from the local Ethics Committee and, in accordance with the declaration of Helsinki, each participant gave informed written consent to participate before the beginning of the experiment. They received an inconvenience allowance at the end of the session.

8.3.2. Task and procedure.

At the beginning of the experimental session, participants completed a series of questionnaires to use as a self-reported measure of emotionally relevant personality traits. In particular, the questionnaires administered included: Carver-White questionnaire (Carver & White, 1994); Sensitivity to Reward/Punishment Questionnaire SPSRQ-35 (Torrubia, Ávila, Moltó & Caseras, 2001); Dickman's Impulsivity Inventory DII

(Dickman, 1990); State-Trait Anxiety Inventory STAI-Y (Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983). They were used to establish, respectively, the degree of dominance for the Behavioural Activation/Inhibition Systems; the sensitivity to reward- and punishment-eliciting stimuli (which is an alternative way to assess BIS/BAS dominance), the level of trait impulsivity and the level of trait anxiety. The last two, according to Gray (1981), are the "operative traits" that modulate the Activation and Inhibition systems respectively and can be taken as measures of the BIS/BAS individual levels. Immediately after, they completed a valence judgement task interspersed with emotional distractors. As illustrated in Fig. 26, each trial started with a fixation cross displayed for 1000ms; then an emotional distractor appeared on the screen for 500ms followed by an emotional target overlapping the distractor for 500ms. During the presentation of the targets, the distractors remained on the screen. Trials ended with an inter-trial interval of variable duration between 2000 and 4000ms after the simultaneous offset of targets and distractors (not shown in the figure). Size of the targets was reduced and their opacity lowered to ensure a partial vision of the distractor during the presentation of the target but allowing, at the same time, a full detection of the target. The optimal values for all the measures (visual parameters and presentation timing) have been obtained through a series of pilot studies that preceded the current experiment (results of the pilot studies are omitted). Opacity for the targets was kept at 85% of the original value; opacity of the distractor at 50% of the original value. An example of a trial containing words as stimuli is displayed in Fig. 27.

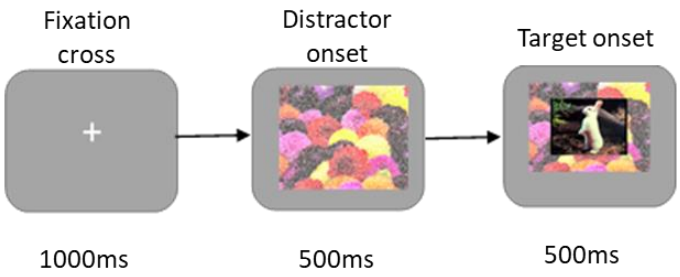


Fig. 26 – Timeline for the experimental design.

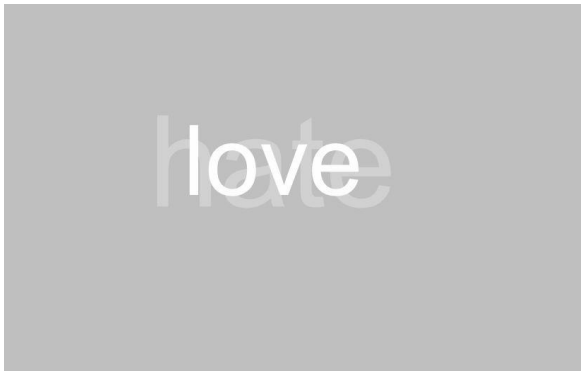


Fig. 27 – Example of a trial containing affective words, as it appeared during the presentation seen by the participants.

Participants were instructed to provide a response to each trial by pressing a key on an Apple computer keyboard, using only one hand per experimental block according to the instructions on the screen. Using the index and middle fingers, they were asked to respond by pressing two different keys if the target stimulus overlapping the distractor was positive or negative. Participants were asked to respond to each trial in the fastest and most accurate way possible. The valence of targets and distractors was congruent for all trials (i.e. a positive target always overlapped a positive distractor, same for the negatives). The combination of keys was different for the two hands to ensure that no habituation effect influenced the responses. The onset of the target on the pc screen marked the beginning of the time segment used to calculate RTs. Each participant completed four blocks of trials; two of the blocks required a response using the right hand; two

required a left-hand response. For each hand, one of the two blocks contained emotional pictures as targets and distractors; the other block contained instead emotional words. Each block was composed of 30 trials; half of the trials contained a positive target, the remaining half a negative one. Before the actual start of each block, participants completed a short (5 trials) practice block to get familiar with the structure of the trials, the pace of the presentation and the keys to be pressed to provide their responses.

At the end of the four blocks, participants viewed a set of thirty emotional pictures and thirty emotional words, evenly split into positive and negative. They were asked to rate the pleasantness of each element on a 9-point scale; subsequently, they stated whether the picture had been presented during the RT task or it was being displayed for the first time. Stimuli appeared for 3000ms and were preceded by a fixation cross, displayed for 2000ms, appearing on the screen after the responses to the antecedent trial were provided. Participants were unaware of the presence of this last block although were told, during the experiment, not to focus only on the cognitive task but to pay attention to the distractors too.

8.3.3. Stimuli used.

For the valence judgement task, we employed 48 positive and 48 negative pictures from the NAPS database and 48 positive and 48 negative words from the Warriner database as emotional stimuli. Half of the elements have been used as targets, the other half as distractors. All the stimuli employed in the current experiment have been already used in the study illustrated in the previous chapter, in order to allow a full comparison for the results across the two studies with regard to the effects of the distractors.

Although the distractor-target match in each trial was different, the criteria used to create each pair of stimuli was identical in the two studies: the only difference was the valence of the target associated to each distractor (congruent in the present experiment, opposite in the previous one). For the pictures, within each valence level and experimental block, we balanced the choice in terms of content (people, objects, animals, human faces and natural scenes) and physical properties. For the words, we selected only verbs with abstract content and a total length between three and eight letters (i.e. love, hate). We excluded words strongly related to motor actions (i.e. 'push', 'pull') since they could potentially alter the RTs between the dominant and non-dominant hand (Dreyer et al., 2015; Pulvermüller, 2013; Pulvermüller, Moseley, Egorova, Shebani & Boulenger, 2014). A word has been categorized as abstract if it "describes internal states of the body", in contrast to action words, which are "semantically related to actions typically performed by moving different parts of the body (such as "talk" and "walk"), which activate body-part–specific representations in sensorimotor cortex" (Moseley, Carota, Hauk, Mohr & Pulvermuller, 2012, p. 1635). Action words can have also positive and negative valence (for example, "hug" Vs "stab"). Therefore, for the purpose of a valence judgement task, both categories of words could have been employed with equally valid choice criteria since both fall under the definition of "emotional words". However, their link with motor execution is tighter and can lead to differences in task performance between the dominant and non-dominant hand due to the mapping, planning and execution of the action expressed by the word. For this reason, we decided to employ exclusively abstract words.

The criterion of complexity for the composition of the pictures was equated with the criterion of familiarity of the words: high-complexity pictures were matched with less familiar words, while

low-complexity pictures were matched with words that are more familiar. Classification of pictures was based on visual inspection of the composition, under the hypothesis of a clear object background Vs scene composition for the two levels of complexity. Words familiarity has been established following the norms provided by Stadthagen-Gonzalez and Davis (2006).

Within the blocks containing emotional pictures, the target matched with each distractor differed in terms of the content of the pictures but was fully randomised in terms of complexity of the two stimuli. For the trials containing emotional words, the length of the distractors was always superior to the targets, in order to allow a full overlap of the target with the distractor itself.

In the memory task that followed the RT task, we selected 30 positive and 30 negative stimuli, half of which were pictures and half words per valence level, 67% of which have been already presented during the RT task and the remaining 33% were new to the participants. Across the previously displayed stimuli, half of them were targets and the remaining half have been presented as distractors. The new stimuli, both words and pictures, were selected on the same criteria for valence and arousal; the previously seen distractors were instead selected randomly within the pool of stimuli used in the RT task.

8.3.4. Statistical analysis.

For the Carver-White questionnaire, overall BIS/BAS dominance was established by the means of t-tests on the average scores for the two Activation and Inhibition scales. We did not use overall scores due to the different number of items that each scale presents within the questionnaire. For the SPSRQ, sensitivity to reward/punishment has been calculated as the overall score of the two subscales due to the homogeneity in the number of elements

present in the two. The dominance of Reward-Punishment system was established by the means of t-tests on the overall score of the SP and SR subscales.

The degrees of trait impulsivity and anxiety from the DII and STAI-Y questionnaires have been calculated as the overall score of each scale.

With regard to the behavioural data, the RTs for the cognitive task have been analysed by means of 2 x 2 x 2 ANOVA (Distractor Complexity: Low Vs High; Valence: Negative Vs Positive; Type: Picture Vs Word). The same statistical test structure has been used to assess task accuracy. In both cases, responses with the left and right hands have been averaged across conditions. Due to the simultaneous presence of these three factors, and due to the results obtained in our previous studies, we decided to direct our attention only on the aforementioned parameters, not including the hand of response as a fourth factor. Our previous analyses on the hand of response factor were inconsistent and, possibly, not related to exclusively to the presence of emotional distractors. Instead, we preferred to focus on the analysis of three factors that, potentially, would provide the strongest information on the effects of distracting stimuli on task performance. By averaging the responses provided with the left and right hand, we also added robustness to effects of the three selected factors, by doubling the numbers of the trials belonging to each factor group. We judged this would be the optimal design to study the effects we are interested in, reserving the inclusion of the hand of response parameter in a second moment, once the effects of the three analysed factors are assessed.

For the memory task, performance was analysed by means of 2 x 2 ANOVA (Type: Picture Vs Word; Valence: Negative Vs Positive). Two separate analyses were conducted for the new stimuli and the previously displayed distractors during the RT task.

Trait-performance correlations were calculated as Pearson's Correlation Coefficient between RTs in response to specific task conditions and individual scores for the BIS/BAS dominance, trait impulsivity and trait anxiety scales. In particular, for the trials containing positive stimuli, RTs for both low and high complexity distractors have been correlated with BAS dominance, trait impulsivity and sensitivity to reward questionnaires scores. For the trials containing negative stimuli, RTs for both low and high complexity distractors have been correlated with BIS dominance, trait anxiety and sensitivity to punishment questionnaires scores.

The statistical threshold was set at $p < 0.05$ and we applied Bonferroni corrections for multiple comparisons where appropriate. Throughout the Results section, mean scores ± SE are reported.

8.3.5. Data pre-processing.

For the statistical analysis, we excluded the trials that received an incorrect response (errors). We marked as errors also the trials that received a double response, either if the first response was wrong and the second correct, or vice versa. Moreover, the trials that did not receive a response (missed trials) were considered as errors and therefore included in the accuracy, but not in the RTs, analysis.

After this first step and before the statistical analysis, we applied an outlier exclusion correction on individual trials on the grounds of the individual speed of response. In particular, within each participant, we calculated the Means (Ms) and Standard Deviations (SDs) for the trials containing either pictures or words and excluded from the analysis all the trials falling outside the range of M±2SDs within each distractor type level, as considered significantly anticipated or delayed responses. The trials excluded were not considered for the RTs nor the accuracy analyses. The

remaining trials were used for the statistical analysis outlined in the previous subsection. Overall, in the current study, the rejection rate was inferior to 5% of the total trials; the highest rejection rate in a participant was 11.6%.

8.4. Results.

8.4.1. Behavioural dominance.

For the Carver-White questionnaire, no significant difference has been found between the average BAS and average BIS scores. For the SPSRQ questionnaire, no significant difference has been found between the SP and SR scales. In both tests, level of significance was $p>0.3$. Therefore, the behavioural dominance of the participants was heterogeneous and not driven towards one of the two systems.

8.4.2. RT task analysis.

For the RTs, there was a significant main effect of Type ($F(1,28)=25.58$, $p<0.001$, partial $\eta^2=0.48$). Trials containing words as stimuli received significantly faster responses than trials containing pictures as stimuli ($M_W=688\pm32$ms; $M_P=902\pm39$ms).

There was also a significant Distractor Complexity x Valence interaction ($F(1,28)=13.38$, $p=0.001$, partial $\eta^2=0.32$). Post-hoc comparisons highlighted how in the presence of high-complex distractors, positive trials received significantly faster responses than negative trials ($M_P= 721\pm34$ ms; $M_N= 763\pm35$ ms; $p<0.01$). The same comparison for trials containing low-complex distractors did not reach statistical significance (Fig. 28). Participants provided significantly faster responses to positive than negative trials only when the preceding distractor had high perceptual complexity,

independent of the type of stimulus employed. Main effects for the remaining factors, as well as the remaining interactions across the factors, did not reach statistical significance ($F<2.8$; $p>0.1$).

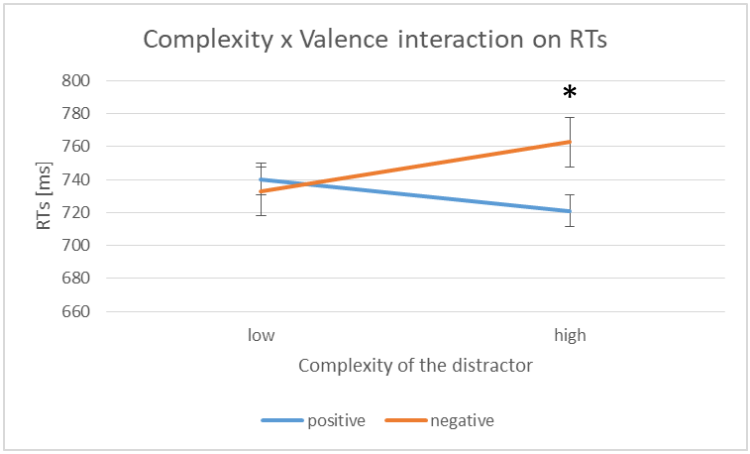


Fig. 28 - The graph displays the significant Complexity x Valence interaction on RTs [ms] during the completion of the valence judgement task. Blue line: responses to trials containing a positive distractor; orange line: responses to trials containing a negative distractor. RTs are reported on the y-axis. Complexity of the distractor is reported on the x-axis.

For the accuracy scores, there was a significant main effect of Type ($F(1,28)= 5.69$, $p<0.03$, partial $\eta^2=0.17$). Trials containing words as stimuli received significantly more accurate responses than trials containing pictures as stimuli ($M_W=93.6\%\pm1.0\%$; $M_P=96.0\%\pm0.7\%$). The remaining main effects did not reach the significance threshold, nor did the interactions across the factors ($F<2.50$; $p>0.1$).

8.4.3. Memory task analysis.

For the newly displayed emotional stimuli, there was a significant main effect of Type ($F(1,28)=4.90$; $p<0.05$, partial $\eta^2=0.15$). Classification of emotional pictures was significantly more accurate

than the classification of emotional words (M_P=79.6%±3.3%; M_W=72.0%±2.9%). There was no significant main effect of valence nor a significant interaction between the two factors (p>0.1).

For the previously displayed emotional distractors, there was a significant Type x Valence interaction (F(1,28)=22.71, p<0.001, partial η^2=0.45). Post-hoc comparison highlighted how negative pictures were remembered significantly better than positive pictures (p<0.02; means: M_N=79.0%±2.6%; M_P=71.4%±3.1%). Simultaneously, positive words were remembered significantly better than negative words (p<0.005; means: M_P=78.3% ± 2.4%; M_N=64.5% ± 3.6%) (Fig 29).

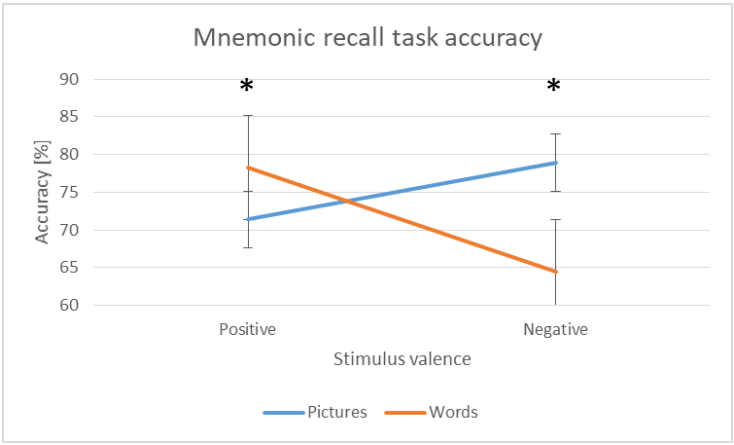


Fig. 29 – The graph displays the significant Type x Valence interaction on accuracy scores [%] during the completion of the mnemonic recollection task. Blue line: trials containing pictures as stimuli; orange line: trials containing words as stimuli. Percentage of correct responses are reported on the y-axis in both graphs. Valence of the stimulus presented is reported on the x-axis.

8.4.4. Trait-performance correlations.

No correlation, among the ones computed between task RTs and individual personality traits, reached the significance threshold.

8.5. Discussion.

The present study aimed to analyse the effect of different types of emotional distractors on the performance of an emotionally salient cognitive task, particularly in light of the specific properties of the distractors (complexity of pictorial composition and familiarity of words). The valence of the targets and distractors presented in each trial was homogeneous: a positive target followed a positive distractor; a negative target followed a negative distractor. This design exalted stronger differences between words and pictures in task completion, the former type receiving significantly faster and more accurate responses than the latter. Moreover, responses to valent target pictures appeared to be modulated by the complexity of the precedent distractor more than the written stimuli.

The mnemonic recall of emotional stimuli followed a pattern of significantly increased accuracy for positive words and negative pictures, while previously unseen pictures received significantly better classification compared to the words.

Finally, the presence of congruent cues preceding the task targets masked any modulatory effect from personality traits that were instead highlighted in the incongruent condition.

8.5.1. Task performance: a clear difference between types of stimuli employed.

Analysis of behavioural measures of task performance pointed out at relevant differences between emotional words and pictures: the former received significantly faster and more accurate responses than the latter. Importantly, the result is not affected by the complexity of the distractor preceding the target nor by the valence of the stimuli considered. We interpret this finding in terms of different emotional salience of the two types of stimuli. This is in agreement with past research suggesting how pictorial stimuli

would require stronger emotional processing than written stimuli, which in turn would undergo a more direct cognitive processing (Carretié et al., 2008; Keil, 2006; Sakaki, Niki, & Mather, 2012). This weaker emotional impact would facilitate the disentanglement of attentional resources from the emotional to the cognitive content, therefore speeding up task completion, not only without any speed-accuracy trade-off but even with a significant increase in the quality of the responses. Flaisch and colleagues (2015) reported similar findings in a valence judgement task using emotional words and pictures. They simultaneously presented the two stimuli within the same trial, the words overlapping the pictures: their participants were asked to respond only to either words or pictures, while the other stimulus worked as a distractor. They determined, at the brain level, stronger activations in emotion-related areas for pictures compared to the words. Using fMRI techniques, they showed significantly increased activity in a continuous network encompassing posterior, frontal, temporal and subcortical regions when the participants responded to pictures than to words. We had already proposed, in the studies reported in the previous chapters, the idea of a different affective salience between words and pictures, particularly at the mnemonic recall level. Here, possibly due to the presence of a congruent cue preceding task response, such an effect was present also at the task level. Therefore, our results suggest that in a condition of absent target-distractor conflict in valence, the lower emotional salience of written than pictorial stimuli would lead to faster and more accurate responses to an associated task.

8.5.2. Stimuli properties: how perceptual complexity affects differently the valence judgement of congruent stimuli.

The specific properties of the stimuli –picture composition and word familiarity- appeared able to manifest their effects on the responses provided to the valence judgement task. In fact, in the presence of high-complex distractors, positive targets received significantly faster responses than negative targets. High-complex stimuli have been classified as less emotionally salient than the ones with lower perceptual load: this is the case for both pictorial and written stimuli (Citron, Weekes & Ferstl, 2014; Berlyne, 1970; Eisenman, 1967; Sianipar, van Groenestijn & Dijkstra, 2016). In particular, the higher the complexity of the composition of a picture or the lower the familiarity of a word, then the lower the emotional salience of the stimulus, determined in terms of decreased valence rating or response accuracy in an aesthetic judgement task. Therefore, weaker distractors, having a lower emotional impact, would be processed more easily, allowing the participants to focus more rapidly on the subsequent target and task response. In a condition of target-distractor affective congruence, in the presence of weaker distractors, valence judgement is significantly faster for positive stimuli. This result is in agreement with other studies taking into account both emotional pictures and words, which similarly found an advantage in response to positive stimuli in affective judgement tasks (Becker, 2012; Frewen, Dozois, Joanisse, & Neufeld, 2008; Kuperman, Estes, Brysbaert, & Warriner, 2014; Robinson, Storbeck, Meier, & Kirkeby, 2004). Our interpretation of the proposed result is, therefore, that low-complex positive and negative distractors would equally capture attentional resources, leading to non-significant differences in the response to the valence judgement of a subsequent target. Instead, high-complex distractors appear to

be disentangled from attention more easily, bringing to a faster engagement of the new stimulus, in which the specific valence of the target drives the speed of response. This result is new in the literature: to date, to our knowledge, no study had previously analysed the effect of complexity of a distracting stimulus and its influence on an emotionally salient task.

8.5.3. Mnemonic recall task: the interaction between the type and the valence of the stimuli.

An interesting result of the current study concerns the mnemonic recall task that followed the RTs task. With regard to the classification of new stimuli, responses to pictures were significantly more accurate than the ones to newly displayed words. This finding is in line with the body of literature supporting the idea that emotional pictures would hold a higher emotional salience than words. This would explain the illustrated effect, since the higher emotional connotation of emotional pictures, independently from the colour of the emotion displayed, led to a better performance in a recognition task, as also suggested by previous works (Park, Puglisi & Sovacool, 1983).

Recollection of previously presented stimuli highlighted instead an extremely interesting pattern of responses: classification of negative pictures was in fact significantly more accurate compared to the negative words, while instead positive words received significantly more accurate responses than the positive pictures. This interaction between type of stimulus and its valence has been previously highlighted in the literature (Bayer & Schacht, 2014; Kensinger & Schacter, 2006). These works suggested a positivity bias for emotional words and a negative offset for emotional pictures at both behavioural (RTs for similar tasks) and brain activation levels (EEG ERPs, fMRI BOLD signal in response to the

specific stimuli). The findings align with a theory proposed by Cacioppo and Gardner (1999), according to which there is a tendency to perceive more easily positive stimuli, compared to the negative ones, when these are low-arousing and, conversely, to favour the processing of negative stimuli, compared to the positive, when these are high-arousing. Affective pictures have been found to be more arousing than words in terms of emotional impact, hence the interpretation of the aforementioned effect in line with Cacioppo's theory. The current study adds another tile to the described mosaic since it reports the same bias for the two types of valent stimuli in the context of mnemonic recall following a cognitive task. Therefore, this interaction would apply as well to a condition of purely incidental learning: this extends what has been previously theorised for explicitly attended stimuli.

8.5.4. Limitations of the current study and future directions.

The current study complemented, in terms of design, the one presented in the previous chapter, describing the effects of different types of valent emotional distractors in the context of a valence judgement task, in which targets and distractors held congruent valence levels.

A limitation of the current design could lie in the lack of interaction between the two types of stimuli. Past research studied the effects of emotional words superimposed to emotional pictures to test how the response to one of the two elements is affected by the presence of the other (Beall & Herbert, 2008; Ovaysikia, Tahir, Chan & DeSouza, 2011; Rosinski, Golinkoff & Kukish, 1975). Our paradigm allows us to separate the effects of the two types of stimuli; however, testing the influence of stimulus complexity in a cross-modality presentation (words overlapping

congruent/incongruent pictures) would help to clarify how specific properties and salience of the affective stimuli would play a role in emotional distraction.

9. General discussion.

The present body of research outlined a series of novel findings on the effects of emotional stimuli on the completion of cognitive tasks, adding new knowledge to the field of emotional distraction.

In our five studies, we initially evaluated the role of valence in emotional distraction, studying the effects of positive Vs negative stimuli on task performance. After analysing the impact of task demands, we determined similarities and differences between affective words and pictures used as distractors on affectively neutral or salient tasks. In the latter case, we also considered the impact of the perceptual complexity of the emotional distractors.

Within all the studies, we analysed the rate of mnemonic recall of the distractors presented, although they were never explicitly attended, and the possible association between task performance (RTs and accuracy rates) and individual personality traits of behavioural dominance.

Across all the five experiments, we were able to define a different effect for positive and negative distractors on task performance, the latter having more detrimental effects. The type of distractor influenced differently the completion of the task and the mnemonic recall of the stimuli, possibly due to a difference in salience between affective pictures and words. The perceptual complexity of the distractors and the affective salience of the task employed can also play a role in the interaction between the emotional distractors and task performance. Eventually, an association between individual personality traits and task performance hinted at the relevance of behavioural dominance in the study of emotional distraction.

This brief overview highlights several consistent results across all the studies performed, despite the changes in the variables

manipulated and the designs proposed. Each of them will be discussed in the following sections in light of the current literature in the field.

9.1. The effects of valence: positive and negative distractors behave differently.

The first and possibly most stable finding of this body of research is the relevance of valence in shaping the effects of emotional distractors on task completion.

A different impact of positive and negative emotional distractors was consistently replicated. This was the first source of conflict between two opposite theories in the current literature that we settled in a precise direction. In fact, a group of studies determined similar effects of positive and negative emotional stimuli, which are only distinguishable from a neutral, non-emotional condition (Gilboa-Schechtman, Foa & Amir, 1999; Muller, Andersen & Hindi Attar, 2011; Muller, Andersen & Keil, 2008). Another stream of studies, instead, highlighted differences between the two valence levels of the emotional stimuli when influencing the completion of a task (Balconi & Ferrari, 2012; Carretié et al., 2013; Vromen, Lipp, Remington & Becker, 2016). Our research, in all studies, delineated a different role for positive and negative distractors, either as purely depending on the valence level of the stimuli (Studies 1 and 2), or interacting in a heterogeneous way with specific features of the stimuli as type or complexity (Studies 3-5). It is interesting to note how the specific properties of the stimuli affected significantly their influence on task performance: in fact, when these variables are not manipulated, a pure effect of valence is present; as they get

controlled within the experimental design, as we did in the last three studies, valence appears to be tightly linked to them.

Therefore, we suggest that positive and negative stimuli hold different emotional features and bring different effects on task completion. Some works present in the literature defined an "emotional" or "affective" condition, contrasted against a neutral baseline, with only one valence level of emotional stimuli analysed -negative, in the majority of the cases (Keil, Moratti, Sabatinelli, Bradley & Lang, 2005; Most, Chun, Widders & Zald, 2005; Schönwald & Müller, 2014). We warn about such a misuse of the term "emotional" since, especially in the field of emotional distraction, emotionally salient stimuli can be either positive or negative and this difference leads to dissimilar effects on task performance.

Positive emotional distractors robustly led to a significantly better performance (in terms of reduced RTs and increased accuracy) compared to the negative ones. This is in line with several past works, which similarly outlined an advantage brought in by positive distractors on task performance (Carboni, Kessel, Capilla & Carretié, 2017; Hodsoll, Viding & Lavie, 2011). This advantage is found especially true for pictorial stimuli: one element we carefully controlled was the content of the emotional pictures used. Past research pointed out differences in the processing of emotional stimuli deriving from the content of the images (faces, objects, scenes, etc.), especially regarding the brain activity generated in response, but also in terms of behavioural differences when used as task-irrelevant distractors (Carretié et al., 2013; Vuilleumier, Armony, Driver & Dolan, 2001). For this reason, we balanced throughout all the five experiments the content of the stimuli, making the highlighted effects of valence independent from the content of the pictorial stimuli.

Moreover, within this body of research, arousal level of the stimuli has been controlled and kept neutral. Arousal has been linked, in past research, to the motivational direction of emotion (approach-withdrawal) (Citron, Abugaber & Herbert, 2016; Citron, Weekes & Ferstl, 2014; Kosonogov, Sanchez-Navarro, Martinez-Selva, Torrente & Carrillo-Verdejo, 2016). The appetitive system is preferentially activated by low-arousing positive stimuli, as the defensive system responds more favourably to high-arousing negative stimuli. Some studies considered low arousing stimuli as neutral (Bouman, Stins & Beek, 2015; Delplanque, Lavoie, Hot, Silvert & Sequeira, 2004; Keil et al., 2002). In our opinion, such an interpretation is not only misleading but also conceptually unjustifiable. Considering the solely high-arousing stimuli as emotionally charged would mean, theoretically, collapsing the valence-arousal plane into a semi-space where, below the mid-arousing level, valence ceases to exist. Thus, calm-inducing and sadness-inducing stimuli would be considered equivalent in terms of valence, being both low-arousing emotions. Along with these theoretical considerations, the best empirical demonstration of the emotional salience of low-arousing stimuli is the differential role that positive and negative distractors have on task completion. Under the assumption of emotional neutrality, no such difference is expected to arise simply because the point of neutrality would not account for two possible levels. Moreover, due to the interacting nature of the two dimensions, the study of one of the two variables must contemplate the careful and systematic control of the omitted one (Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000; Robinson, Storbeck, Meier & Kirkeby, 2004). This does not mean necessarily its exclusion, as we chose to do: it is essential, however, that stimuli are matched with the same level of the controlled variable, even in the comparison against a neutral baseline. The stability of our results across studies, generated

using low-arousing stimuli, allows ascribing them exclusively to the valence of the distractors, without any influence from arousal.

Therefore, the novel element this research adds to the current literature is the determination of the beneficial effects of positive distractors on task performance, a result immune from any contamination of the dimension of arousal and, specifically for the emotional pictures, from the scene depicted.

9.2. The effects of type of stimuli: emotional words and pictures do not hold the same distracting properties.

The second relevant finding of the current research is the determination of several differences between emotional words and pictures when used as emotional distractors. The present work helped fill a gap present in the literature, lacking a direct comparison of the two types of emotional stimuli in terms of salience and distracting power. From the three studies (Studies 3-5) that employed the two types of stimuli, we determined important differences between words and pictures at the task level, when they have been used as distracting stimuli.

With regard to these effects, past research had highlighted a different behaviour of the two types of stimuli in the context of emotional distraction, especially in light of their valence level. For the emotional pictures, a difference between positive and negative stimuli has often been suggested (Dreisbach, 2006; Dreisbach & Goschke, 2004; Ihssen, Heim & Keil, 2007; Sakaki, Gorlick & Mather, 2011). These works often determined stronger disruptive effects on task performance from negative, compared to positive, distractors. For the emotional words, instead, the distracting effects on task performance of positive and negative elements

have often been found to be similar (Anderson, 2005; Jackson, Linden & Raymond, 2012; Kousta, Vinson, & Vigliocco, 2009). Only a few exceptions determined a higher disruptive effect of negative, compared to positive, words on task completion (cf. Estes & Adelman, 2008; McKenna & Sharma, 1995). Our results appeared to be initially in countertendency with this trend: in fact (Study 3), firstly we found a different behaviour between positive and negative words, in the direction of increased accuracy rates for the former, but not between positive and negative pictures. However, in Study 3, the associated task did not hold any emotional salience (numerical magnitude comparison). When the type of task is changed (Study 4) and holds higher emotional salience (valence judgement), the effects of distracting words and pictures are reversed and aligned to the trend seen in the literature. Here we observed a significant difference between positive and negative emotional pictures, with the former distractors leading to significantly lower RTs, while no differences have been recorded between positive and negative distracting words. It is also worth noticing how only the results of Study 3 failed to replicate an otherwise fully coherent pattern of differences in the effects of positive and negative distracting pictures detected across Studies 1-4, where the same effect (even with different specific pictures selected from two distinct databases) has been repeatedly found. A pattern that, in terms of the direction of the aforementioned effect, is in line with previous studies highlighting a facilitation from positive affective stimuli on task completion (Masuda, 2015; Rowe, Hirsh & Anderson, 2007; Schmitz, De Rosa & Anderson, 2009; Storbeck & Clore, 2008). Eventually, results of Study 5 suggested a more straightforward difference between emotional words and pictures in terms of significantly faster RTs for the former.

Overall, the results are consistent with the hypothesis of a significant difference between emotional words and pictures when employed as task-irrelevant distractors. This result has been already suggested by past studies that interpreted this discrepancy in terms of a different salience between the two types of stimuli, the pictorial ones holding superior emotional charge than the written ones (Paivio & Csapo, 1973; Shepard, 1967). This could in principle explain the dissimilarities encountered between the valence levels of the two types of stimuli. If they are less salient, as in the case of the written distractors, they are perceived as closer to the neutrality point, leading to weaker differences between positive and negative elements. However, when the processing of the stimuli involves task-irrelevant distractors, the absolute valence of the stimuli –as defined by their normative ratings- would still exhibit its effects on the completion of a task, leading to the differences between positive and negative distracting words (Study 3). Instead, when the processing of the stimuli becomes explicit (Studies 4-5), the differences would be once again not manifested.

The series of studies performed adds several relevant results to the current research framework on emotional distraction. In the first instance, it helped fill a relevant gap present in the literature, where a direct systematic comparison between emotional words and pictures used as emotional distractors was absent. By doing this, it was possible to point out how the two types of stimuli elicit different effects on task performance. In particular, our results suggest how the behaviour of written and pictorial stimuli could be similar when the task they are interspersed with does not hold any emotional feature. When instead the affective charge of the task is stronger, positive and negative distracting pictures display a different behaviour, while distracting words did not show relevant

differences between the two valence levels. This difference between types of stimuli can in principle be ascribed to the dissimilar salience of the stimuli. Thus, we suggest that the previous findings on different connotations between the two types of stimuli could be extended also to the condition of processing where the stimuli are not an active component of the task, as it happens when used as task-irrelevant elements.

9.3. The memory of emotional distractors: how the valence and the type of the stimuli affect mnemonic recall.

A further element of difference between affective words and pictures comes from the analysis of the mnemonic recollection and classification of the distractors that followed the RT tasks.

The most relevant result in this second task, fully stable across the three studies in which we compared written and pictorial stimuli, is a significantly better performance in both recollection (correct response to previously displayed stimuli) and classification (correct response to newly displayed stimuli) of emotional pictures, compared to the words. This difference can be interpreted again in terms of higher emotional salience of pictorial, compared to written, stimuli. Past research has studied the effects of emotional stimuli on mnemonic performance, however often using a dual stage presentation task as experimental paradigm: in this case, a series of pictures or words are presented to the participant, in the encoding phase (Grady, Mcintosh, Rajah & Craik, 1998; Kohler, Moscovitch, Winocur & McIntosh, 2000; Paivio & Csapo, 1971). Subsequently, during the recall phase, a mix of the elements already displayed and new stimuli is presented to the participant, who has to classify each element as new or previously seen.

Interestingly, along with the highlighted differences between the two types of stimuli, in our research valence appears to influence the recollection and classification process for the emotional pictures more than for the written stimuli, in a consistent trend. Negative pictures, in fact, are recalled and classified better than the positive ones, even in the condition of low arousal, although this latter variable appears to be the best modulator of mnemonic recall (Marchewka et al., 2016; McGaugh, 2013). Past research suggested that negative pictures are capable of gathering more attentional resources than the positive counterpart does, possibly to a higher relevance for survival than the positive stimuli (Mogg et al., 2000; Nobata, Hakoda, & Ninose, 2010; Okon-Singer et al., 2007; Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008).

With regard to the words, instead, this difference between positive and negative stimuli was never present in the classification task performed in all the three studies (Studies 3-5). Moreover, in two of the three studies (Studies 3 and 4), this difference was absent also in the recollection task. Past literature disagreed on the different effects of positive and negative emotional words in memory-related tasks. Some studies found similar effects of the two (Doerksen & Shimamura, 2001; Dougal & Rotello, 2007; Reber, Perrig, Flammer & Walter, 1994). Others pointed out significant differences, with an advantage for recalling pleasant stimuli over negative ones (Carou et al., 2011; Herbert, Junghofer & Kissler, 2008; Kissler, Herbert, Winkler & Junghofer, 2009). Our results support the idea that, when presented as emotional distractors and therefore not as a relevant part of the task, positive and negative words would bring only marginal differences in recall rates and in the classification of new stimuli.

It is interesting to note how past research theorised the existence of a positive offset for emotional words and a negative bias for

emotional pictures (Bayer & Schacht, 2014; Kensinger & Schacter, 2006; Liu, Jin, Wang & Hu, 2010). This trend has been fully replicated, in our research, only in the recollection task of the last experiment. In fact, while the negative bias for emotional pictures has been more consistently reported across our studies, the positive offset for words was harder to reproduce. Therefore, our results suggest how the interactive effect cannot be, in principle, expected to be found after the presentation of emotional stimuli as distractors: in fact, especially for the written stimuli, a consistent difference in the type of learning (that is, whether the stimuli are attended as part of the task or only as irrelevant elements in the stream of a concurrent task) would alter the way stimuli are memorised and, subsequently, recalled. Once again, this can be due to the inferior salience of written stimuli: when not explicitly attended, positive and negative emotional words can still affect differently task performance, but the low salience does not allow appreciating any significant difference in a subsequent mnemonic recall.

The additive element proposed in this research is the extension of the aforementioned effects on memory-related tasks to the presentation –and learning- of the stimuli considered. While in a serial presentation participants actually attend the stimuli (and therefore the new ones are considered, misleadingly, as distractors), here the previously shown stimuli are presented in the context of a cognitive task as irrelevant elements, and therefore not explicitly used as a task component but only inserted in the stream of presentation of the concurrent task.

Overall, the current research suggested how emotional words and pictures would hold different properties when used as emotional distractors, particularly regarding the cognitive task they are used in conjunction with. A clearer advantage in the mnemonic recall

appears to be brought by negative distracting pictures compared to the positive ones. With regard to the emotional words, instead, such difference between the two valence levels was weakly detected. This body of studies presented, for the first time, a systematic and direct comparison between two types of emotional distractors, and suggested how the idea that emotional words would have a lower emotional salience than the pictorial stimuli could be extended to the field of emotional distraction, when the processing of the stimuli is fully unrelated to the ongoing task and its completion.

9.4. How the specific properties of emotional distractors influence their effects on task performance.

Both the broader variable of valence and the narrower one of the type of stimulus influence the way an affective distractor can generate an interference with an ongoing cognitive task. However, within each type of stimuli, two adjunctive specific variables appeared to play a significant role in this interaction. For the emotional pictures, it is the complexity of the scene displayed, along with its content; for the written stimuli, instead, the familiarity, along with the concreteness, of the words.

The complexity of the pictorial composition and familiarity of emotional words have been, in the present research (Studies 4 and 5), equated as a stimulus-specific criterion to allow direct comparison between two different types of distractors. Both, in fact, influence at the perceptual level the time needed to process the stimuli. Low-complexity pictures, with a simple object-background composition, tend to benefit from a faster detection and processing compared to high-complex scenes (Jacobsen,

Schubotz, Höfel & Cramon, 2006; Mavratzakis, Herbert & Walla, 2016; Méndez-Bértolo et al., 2016). Symmetrically, familiar words tend to be recognised more easily compared to less familiar ones (Ferré, Fraga, Comesaña & Sánchez-Casas, 2015; Zhang, Liu, An, Yang & Wang, 2015). An illuminating work by Schlochtermeier and colleagues (2013) pointed out how differences in perception of affective words and pictures are not due to a difference in visual complexity between the two types of stimuli but to their inherent affective salience. The debate is, in fact, open to assess whether the affective superiority of pictorial stimuli is due to perceptual features or, being those non-influent, to a pure emotional factor (i.e. if the difference is due to the "form" or the "content") (Caramazza, 1996; Glaser, 1992; Paivio, 1991). The study showed how different modalities of presentation (written and pictorial) generated different activations at the cortical level, but the differences in affective perception (response to the valence level of the single stimuli) are not influenced by this visual discrepancy. While it was found that picture complexity can have an impact on the processing of low- and high-complex pictures, this difference remains confined to the specific type of stimulus and, according to the authors, is not extendible to the written ones. Our results confirm what suggested in the aforementioned work: in fact, in both our studies analysing the complexity of the distractors displayed, results highlighted a stronger influence of this variable on the affective perception of the stimuli and the subsequent response to emotional targets. On the contrary, the influence of the complexity of the distractor does not appear to consistently influence task performance in the presence of a particular type of stimulus. The only difference appearing in Study 4, where low-complex distractors led to significantly more accurate responses to trials containing words compared to pictures, can be interpreted in terms of emotional salience of the stimuli presented. When the

distractor is a familiar word, the lower emotional salience would generate a weaker interference with the processing of the subsequent target, generating higher accuracy rates compared to the pictorial counterpart. However, when analysing the speed of response to the task, such a difference between distracting words and pictures ceases to be significant.

It is worth noticing how, in the past literature, the differences between emotional words and pictures, and the associated properties, have been studied almost exclusively considering the brain activity (EEG or fMRI) in response to the stimuli, but at behavioural level –and in particular employing the affective stimuli as task-irrelevant elements- results are, to our knowledge, non-existent. Through this series of studies, we aimed to fill this gap in the general research framework of affective processing and, specifically, in the field of emotional distraction, supporting and complementing via behavioural measures what has previously been argued by neuroimaging studies (Azizian, Watson, Parvaz, & Squires, 2006; Khateb, Pegna, Michel, Landis & Annoni, 2002; Schendan, Ganis & Kutas, 1998; Vandenberghe, Price, Wise, Josephs & Frackowiak, 1996).

In summary, our results suggest how the perceptual properties, in terms of stimuli complexity, have a strong influence on how the differently valent emotional distractors are processed and on their subsequent effect on task completion. On the contrary, this perceptual variable does not affect differentially written and pictorial stimuli: the –weak- difference across the two types of distractors appears to be due to the affective, and not perceptual, charge held by words and pictures. Secondly, the theorised stronger impact of low-complex emotional stimuli, interpreted in terms of higher salience and faster processing than the high-complex counterpart, can be extended to the field of emotional

distraction: the advantage in task performance brought in by positive distractors, in fact, is strongly modulated by the complexity factor, especially at low perceptual level. When complexity increases –and symmetrically, emotional impact decreases-, this advantage for positive distractors ceases to significantly manifest its effects. Therefore, although not significant in the inter-stimulus comparison, specific properties of the distractors influence the way positive and negative distractors affect task completion.

9.5. The effects of the type of task: distraction does not have homogeneous effects on all cognitive tasks.

The effects of emotional distractors on task performance, however, are not exclusively modulated by stimulus-specific parameters of the task-irrelevant elements, as seen in the previous sections. According to the results obtained in the current research, in fact, the interaction between cognitive and emotional processes appears to be affected, in part, by the features of the concomitant task completed. We studied the specific properties of cognitive tasks in this interplay from three different points of view: the cognitive load required to complete the task (Study 2), the emotional salience of the task (Study 3 Vs Studies 4-5) and the target-distractor congruence (Study 4 Vs Study 5) when both task targets and distractors have relevant affective charge.

With regard to the first hypothesis, our results show how the advantage in task performance due to the presence of positive, compared to negative, distractors appear to be unaffected by the perceptual load of the associated task. This result is in line with other works agreeing on the absence of modulatory effects from

cognitive load in the interaction between valent distractors and task performance (Lavie, 2005; Yang, Wang, Jin & Li, 2015). It is worth noting, however, how most of the studies in the field compared one emotional condition –often negative- with a neutral baseline to assess the effects of task load on emotion.

While cognitive load did not interact with the emotional features of the distractors, a comparison between emotionally salient tasks and ones without any affective connotation highlighted a different behaviour of the distracting stimuli depending on the task. In particular, on an emotionally-neutral task (Study 3), our results indicated a different behaviour for distracting words and pictures, with a more discernible difference across valence levels for the former compared to the latter, always in the direction of an advantage from positive distractors. When the affective charge of the task increases (Studies 4 and 5), instead, the aforementioned pattern of interference appears to be reversed. In this second case, in fact, the pictorial stimuli had a better outlined dissimilar effect in the two valence levels (advantage for responses to trials containing positive, compared to negative, distractors) than the written ones, which in turn do not display significant differences between positive and negative valence. As mentioned in the previous sections, this result can be interpreted in terms of a different emotional impact of the two types of stimuli. When the task does not share affective features with the distractors, emotional words can have differential distracting effects on task performance according to the valence of the stimulus. In emotionally salient tasks, the higher affective charge of the pictorial stimuli allows the expression of significant differences between positive and negative distractors.

We are aware that this type of comparison is indirect, and the results of the two studies come from a different sample of the

population. However, the line of argument maintains its strength considering the homogeneity of the samples analysed: both included only healthy participants with normal –or corrected to normal- vision. Therefore, in principle, any perceptual-related difference (colour blindness, dyslexia, etc.) would not affect the results. Demographic (age and gender), as well as cultural (sample from University students, all native English speakers) variables were tightly controlled in order to eliminate any effect from them. Handedness was also kept at consistent degree, with only right-handed participants tested. For these reasons, the results from each study could be directly compared since they come from homogeneous samples of the same population (and would extend to a population sharing the same connotations). Despite any possible theoretical limitation, in our opinion this is the best –and perhaps only- way to compare the influences of emotional distractors on different types of task. We employed the same distractors on different tasks for this purpose; moreover, asking the same participant to complete the two tasks would have biased the results in terms of novelty effects of the emotional stimuli. Past research has in fact pointed out how the impact of repeatedly presented emotional stimuli progressively decreases in terms of both associated brain activity and speed of response to them (habituation effect) (Moriguchi et al., 2011; Ohman, Hamm & Hugdahl, 2000; Satpute, Hanington & Barrett, 2016; Wright et al., 2001). For these reasons, we decided to use a between-subjects comparison to contrast the results of the different studies, with a high confidence concerning the robustness of this process due to the aforementioned experimental choices.

Eventually, the last task-related factor modulating the emotion-cognition interaction is the valence congruence of targets and distractors in an emotionally salient cognitive task. In one of the

two studies performed (Study 4) the target stimulus, object of a valence judgement response, was always preceded by an incongruent distractor; in the following experiment (Study 5) the two elements had instead congruent valence. In the first case, not only the complexity of the distractors played a stronger role in modulating task responses, as previously discussed but also, especially for the pictorial stimuli, a significant advantage in task performance was present for the positive distractor-negative target combination of trials. This effect could have been due either to faster responses to negative targets or to a facilitation effect from positive distractors. The reduction of RTs -even though significant only for high-complex distractors- for the positive stimuli in the congruent condition allows thinking that, in both cases, the positive distractors would drive to enhanced task performance independently from the congruence of the subsequent target displayed: an absolute effect particularly prominent for the pictorial stimuli. Therefore, our results suggest that even if the complexity of a distractor can have a different effect while varying the valence incongruence between distractors and targets, the advantage brought in by positive stimuli is weakly affected by this parameter.

Overall, this body of research added novel findings to the field of emotional distraction from the perspective of the concomitant task proposed. Positive distractors, in particular, the pictorial ones, brought an advantage in task performance at different levels of perceptual load in an equal fashion; this advantage remained unaltered when the emotional charge of the associated task changed, and when the congruence of the distractor with the associated target is manipulated. The element of novelty lies in the detection of an advantage for positive distractors despite the manipulation of several task-related variables: this complements,

form the task perspective, what has been previously illustrated at distractor level, corroborating and completing the results of the previous analyses.

9.6. Personality traits: differences in the modulatory effects of BIS and BAS.

One of the most relevant elements of novelty in the current research is the study of emotional distraction in light of individual differences expressed through self-reported measures of personality traits. Past research has highlighted the association of behavioural dominance, calculated through BIS/BAS scales, with several aspects of emotional processing. It robustly correlates with electrophysiological measures like frontal asymmetries in clinical and healthy population, in both task and resting conditions (De Pascalis, Cozzuto, Caprara & Alessandri, 2013; Diego, Field & Hernandez-Reif, 2001; Harmon-Jones & Allen, 1997; Schneider et al., 2016). It also correlates with behavioural measures like ratings of emotional stimuli or task-related performance, particularly concerning the mnemonic recall of the stimuli (Balconi et al., 2012; Gable & Poole, 2014; Kim, Yoon, Kim, & Hamann, 2015; Savine, Beck, Edwards, Chiew, & Braver, 2010). However, how these traits can play a role in the processing of task-irrelevant, although emotionally salient, elements was scarcely –if not never- analysed previously.

Our results across all the studies –with the exception of Study 5, where any correlation analysis did not reach statistical significance- point in the direction of an association between the advantage in task performance due to the positive distractors at individual bases, with the absolute BAS dominance levels but also the associated measures –for example, trait impulsiveness-.

In the present research, we always tested the correlation for both BAS and BIS dominance, and the related traits of impulsivity and anxiety, with the completion of the task in the presence of a homologous distractor (i.e., BAS dominance and performance in the presence of positive distractors, BIS dominance and performance in the presence of negative stimuli). However, a modulatory effect was expressed exclusively between BAS dominance and perception of positive distractors. Moreover, this result appeared independent from the dominance of the population sample analysed. In fact, in the first study, a significantly BAS-oriented population might have hinted at a bias in the results: since the whole population had strong BAS dominance, then the only obvious modulatory effect would have been expressed at the level of positive distraction. However, even in the absence of such clear connotation for all the participants, as in the following experiments, this modulation remained intact. In addition, the aforementioned modulatory effect of personality traits on task performance did not affect the two types of distractors analysed in the same fashion: in fact, it was substantial for the pictorial stimuli, while negligible for the written ones. This can be interpreted again in terms of a different emotional salience of the two types of stimuli: possibly, the activation of the BAS requires stronger emotional stimuli, as the pictorial ones seem to be. Under adequate stimulation, the behavioural system can express its effect deriving from the perception of the emotional stimulus and influence the subsequent task response by modulating task RTs.

This result leads to a dual consideration. In the first instance, personality traits are a suitable candidate to assess the relationship between emotion and cognition at the individual level: although further research is needed, the results of the current studies suggest that BAS dominance can be associated with the

advantage in the responses to positive stimuli even when these are attended as task-irrelevant elements interspersed with an ongoing cognitive task. *In secundis,* our results might hint at a different role of the inhibition and activation systems. This theory has already been proposed in the literature (Berkman, Lieberman & Gable, 2009; Coan & Allen, 2003; Corr, 2013). While the BAS is found consistently activated by approach-driven stimuli (as positive distractors are), the BIS would work more as a conflict-detection system rather than as the alter ego of the BAS, activated by inhibition-driven stimuli (as negative distractors are). This assertion appears supported at two different levels in our research. In the first instance, by the association between individual BAS levels and task performance expressed in Studies 2 and 3, in which BAS levels, regardless of the absolute behavioural dominance of each participant, inversely correlated with task performance in terms of speed of response when positive distracting pictures are used in combination with the task. In Study 4, instead, we generated a situation of conflict, at the affective level, between the valence of each distractor and the subsequent target. In this case, it is the inhibition system the one associated with the speed of task responses: the higher the sensitivity to this system at the individual level, the faster the conflict is resolved and consequently the faster the responses to task targets are provided. The modulatory effect is expressed, in this case, on negative distractors-positive targets pairs: an absolute advantage in terms of response speed is again present for the trials containing positive distractors, as previously discussed, but here the BIS -and not the BAS- operates the modulation, possibly due to the situation of conflict presented.

Overall, several novel results on the individual differences in the emotion-cognition interplay have been highlighted in the current

research. In the first instance, we suggest how BIS-BAS dominance can affect the way an individual perceives an emotional distractor, especially with positive valence: this parameter, along with its related measures (sensitivity to reward, trait impulsiveness) could be associated at the individual level with the quality of performance in a concomitant task. At the level of emotional distraction, our results support the theory of a BAS system activated by approach-driven stimuli and a BIS system more devoted to the detection and resolution of conflicts rather than a pure symmetrical counterpart of the activation system. When conflicts arise, particularly in the emotional sphere, the levels of BIS dominance and its associated measures (sensitivity to punishment, trait anxiety) could be used as a parameter to assess individual performance in terms of ability to solve the ongoing conflict and provide a response to the associated task. These influences do not appear to be equally effective for all types of emotional distractors: while they appear to be more robust to pictorial stimuli, the effect is significantly weaker for the written ones. Therefore, although a significant advantage in task performance is due to the presence of positive distractors, individual traits could influence the *degree* of this advantage by modulating the benefit from positive distraction. Our results suggest that the previous findings on the relevance of BIS/BAS dominance in emotional processing could be extended to the field of emotional distraction and, possibly, the individual behavioural dominance could be associated with the performance in cognitive tasks interspersed with emotional distractors.

9.7. Limitations and potential applications of the current research.

Despite the attention devoted to the design of each of the experiments presented in this thesis, some limitations can be outlined in the present research.

In the first instance, we could have included a preliminary power analysis for the number of participants needed in each study. While the reported measures of size effect (specifically, the partial η^2 coefficient) in our analyses confirmed that, for most of the significant results found, the statistical power can be considered high (i.e. bigger than 0.2), this type of test could (and perhaps should) have been run a priori rather than ex post. We based our choices about the number of participants on past studies in the literature using similar neuroimaging techniques and experimental materials and on the availability of temporal and monetary resources (i.e. time needed to physically run the experiment and budget constraints). We included, in each study, the highest number of participants available, and the statistical analyses confirmed in the end the validity of this choice.

Another possible limitation could be the absence of a deeper screening of the participants in terms of emotional disorders. We considered, for all the studies, only healthy participants. We screened them on the ability to perceive visual stimuli (i.e. having normal or corrected-to-normal vision), the ability to read words (e.g. without cognitive or perceptive impairments as dyslexia). We asked written questions about the current physical conditions (e.g. participants manifesting fatigue or sleepiness before the test were excluded before starting the experiment) and, of course, the basic parameters required to complete the study (handedness, gender, age, native language, etc.). This was part of the preliminary screening and, clearly, did not include the questionnaires proposed

during the studies (e.g. trait anxiety and impulsivity, behavioural dominance, etc.). On top of these preliminary questionnaires, we could have included other questions specifically focusing on the possible emotional disorders affecting the participants (e.g. PTSD). However, despite the lack of an explicit questionnaire on the possible affective disorders, we provided the participants an information sheet to read before signing the consent form to agree the participation in the studies. In this sheet, we clearly stated that, during the experiment, we would have shown emotionally salient stimuli that, for some participants, these might have been distressing. We also included a picture from the IAPS database as an example of the aversive stimuli that the participant might have encountered during the completion of the computer task. We also plainly stated that the participant was encouraged to withdraw from the experiment as he found the procedure distressing at the emotional level. Moreover, after each block of trials completed by the participants, we asked whether the procedure was distressing and whether they were willing to continue or rather, wished to withdraw. At the end of the experiment, participants have been given a debrief sheet including the contact numbers of the experimenter, the supervisor and several services provided by the University, in case they found the experiment distressing and were in need of psychological support. This series of controls and information, possibly in conjunction with the low arousal level of the stimuli, made no participant choose to withdraw from any study or show any symptom of emotion-related disorder. However, in a potential follow-up of the research described in this thesis, the inclusion of a questionnaire allowing the screening of the participants for potential emotional disorders could be beneficial.

Unlike the first two studies, the last three experiments did not include a neutral baseline to contrast the effects of emotional distractors with a neutral condition. This was a precise

experimental choice. Due to the presence of two types of distractors (written and pictorial), the inclusion of a neutral baseline to flank the two levels of valence of the distractors would have considerably increased the duration of each experimental block. This would have resulted in a (physiological) loss of attention from the participants during the task and, consequently, a significant decrease in the quality of the data collected. To prevent this, we chose to "sacrifice" the neutral baseline for the sake of higher quality in the positive Vs negative comparison, which was the focus of our research. A potential follow-up of this research might, however, focus on the differences between the two emotional conditions and a neutral baseline and include the latter in the experimental design and subsequent analysis.

Along with these flows, several potential applications of the research described in this thesis can be outlined.
Understanding this interaction could have clinical application in the field of attention-related pathologies (e.g. ADHD). Should emotional distractors have a beneficial effect on cognitive performance, as our research suggest (particularly with regard to positive stimuli), then their inclusion in tasks requiring sustained attention to patients with attention deficits would result beneficial. Affective distractors can heighten attention despite being irrelevant to the task, due to their salience: for this reason, they can be included as "attentional boosters" when patients with attentional disorders are asked to focus for long intervals of time.
With a similar line of reasoning, understanding how the individual personality traits can influence the interplay between emotional and cognitive processes can help to create better therapies, individually targeted, to help patients with attentional disorders focusing on a task by using emotionally salient stimuli interspersed with the task itself.

Understanding the physiological mechanisms of affective processing, in terms of interconnected brain areas and structures involved, can help determining the differences between healthy and pathological conditions where the processing of emotional stimuli is impaired or altered (e.g. autism spectrum disorders). Highlighting these differences can have dual importance: on the one hand, it could allow the description of the pathology at the neural level; on the other, it could improve the therapeutic interventions to ameliorate the conditions of the patients.

9.8. Summary of the findings.

Overall, the body of research presented has been able to provide an answer to all the research questions proposed and presented in the introduction of this manuscript. In particular, we aimed to:

- Define the role of valence for the emotional distractors. Our results support the line of studies assigning a different role to positive and negative stimuli in emotional distraction, the former leading to significant advantages, compared to the latter, in task performance in terms of significantly reduced RTs and increased accuracy in the responses provided.
- Define the role of attentional demands and cognitive load of the cognitive task associated with the emotional distractors. Results suggest that cognitive load does not affect the perception of emotional distractors, nor their effects on task completion. Processing of task-irrelevant emotional stimuli appears to be automatic and not related to the availability of cognitive resources not employed by the task.
- Define the role of different types of emotional distractors. Our data suggest a different role for emotional written and pictorial distractors, the latter having a stronger emotional salience than

the former. This difference appears to be expressed not only at the task level, in terms of differential influence on the task and in relation to the valence levels for each type of stimulus, but also concerning the mnemonic recall of the distracting elements.

- Define the relevance of emotional salience in the context of emotional distraction. Our results highlighted a different effect of the same emotional distractors on tasks having different emotional charge. Therefore, we suggest that not only different types of distractors can affect task completion in a heterogeneous way *per se*, but also in relation to the type of task they are interspersed with. A higher emotional charge of the task would lead to stronger interference effects for valent pictorial stimuli, while differences across valence levels for written stimuli could be more appreciable in tasks without significant emotional connotations.
- Define the mnemonic consistency of the task-irrelevant elements. Our research clearly demonstrated how emotional words and pictures do not have the same ability to sediment into participants' memory: the latter exhibit significantly higher accuracy rates in classification and recollection tasks. However, despite this difference, both types of stimuli are remembered after incidental learning: this datum supports the theory that emotional stimuli, although not explicitly attended, are automatically processed and stored in memory.
- Assess whether personality traits relevant to the perception of emotional stimuli (BIS/BAS dominance) can be associated with the responses provided to a task in the presence of specific valent distractors. Our results suggest a different effect from personality traits on the way emotional stimuli influence task performance. This effect appears to be consistent for pictorial stimuli and, in general, more reliable for positive –compared to negative-distractors. We support the idea that the activation system could actually be respondent to approach-driven stimuli, therefore

suitable to modulate the interference of positive distractors on task performance in terms of speed of response. The inhibition system instead appears to be activated when a conflict arises, therefore modulating task responses only in the presence of an explicit conflict (in our case, at the emotional level).

References.

Ackerman, B. P., Abe, J. A. A., & Izard, C. E. (1998). Differential emotions theory and emotional development: Mindful of modularity. *What Develops in Emotional Development?*, 85–106. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=psyc3&NEWS=N&AN=1998-02713-003

Aftanas, L., Varlamov, A., Pavlov, S., Makhnev, V., & Reva, N. (2001). Event-related synchronization and desynchronization during affective processing: emergence of valence-related time-dependent hemispheric asymmetries in theta and upper alpha band. *The International Journal of Neuroscience*, *110*(3–4), 197–219. http://doi.org/10.3109/00207450108986547

Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. *Clinical Psychology Review*. http://doi.org/10.1016/j.cpr.2009.11.004

Amodio, D. M., Master, S. L., Yee, C. M., & Taylor, S. E. (2008). Neurocognitive components of the behavioural inhibition and activation systems: implications for theories of self-regulation. *Psychophysiology*, *45*(1), 11–9. http://doi.org/10.1111/j.1469-8986.2007.00609.x

Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology. General*, *134*(2), 258–81. http://doi.org/10.1037/0096-3445.134.2.258

Andres, M., Seron, X., & Olivier, E. (2005). Hemispheric lateralization of number comparison. *Cognitive Brain Research*, *25*(1), 283–290.

http://doi.org/10.1016/j.cogbrainres.2005.06.002

Ansari, D. (2007). Does the parietal cortex distinguish between "10," "ten," and ten dots? *Neuron*, *53*(2), 165–7. http://doi.org/10.1016/j.neuron.2007.01.001

Anticevic, A., Barch, D. M., & Repovs, G. (2010). Resisting emotional interference: Brain regions facilitating working memory performance during negative distraction. *Cognitive, Affective, & Behavioral Neuroscience*, *10*(2), 159–173. http://doi.org/10.3758/CABN.10.2.159

Aquino, J. M., & Arnell, K. M. (2007). Attention and the processing of emotional words: dissociating effects of arousal. *Psychonomic Bulletin & Review*, *14*(3), 430–435. http://doi.org/10.3758/BF03194084

Augustinova, M., & Ferrand, L. (2014). Automaticity of Word Reading: Evidence From the Semantic Stroop Paradigm. *Current Directions in Psychological Science*, *23*(5), 343–348. http://doi.org/10.1177/0963721414540169

Aydin, S., Demirtaş, S., Ateş, K., & Tunga, M. A. (2016). Emotion Recognition with Eigen Features of Frequency Band Activities Embedded in Induced Brain Oscillations Mediated by Affective Pictures. *International Journal of Neural Systems*, *26*(3), 1650013. http://doi.org/10.1142/S0129065716500131

Azizian, A., Watson, T. D., Parvaz, M. A., & Squires, N. K. (2006). Time course of processes underlying picture and word evaluation: an event-related potential approach. *Brain Topography*, *18*(3), 213–22. http://doi.org/10.1007/s10548-006-0270-9

Balconi, M., & Cobelli, C. (2014). Motivational mechanisms (BAS) and prefrontal cortical activation contribute to recognition

memory for emotional words. rTMS effect on performance and EEG (alpha band) measures. *Brain and Language*, *137*, 77–85. http://doi.org/10.1016/j.bandl.2014.08.006

Balconi, M., Falbo, L., & Brambilla, E. (2009). BIS/BAS responses to emotional cues: Self-report, autonomic measure and alpha band modulation. *Personality and Individual Differences*, *47*(8), 858–863. http://doi.org/10.1016/j.paid.2009.07.004

Balconi, M., Falbo, L., & Conte, V. A. (2012). BIS and BAS correlate with psychophysiological and cortical response systems during aversive and appetitive emotional stimuli processing. *Motivation and Emotion*, *36*(2), 218–231. http://doi.org/10.1007/s11031-011-9244-7

Balconi, M., & Ferrari, C. (2012). rTMS stimulation on left DLPFC increases the correct recognition of memories for emotional target and distractor words. *Cognitive, Affective, & Behavioral Neuroscience*, *12*(3), 589–598. http://doi.org/10.3758/s13415-012-0090-1

Balconi, M., Grippa, E., & Vanutelli, M. E. (2015). What hemodynamic (fNIRS), electrophysiological (EEG) and autonomic integrated measures can tell us about emotional processing. *Brain and Cognition*, *95*, 67–76. http://doi.org/10.1016/j.bandc.2015.02.001

Balconi, M., & Mazza, G. (2009). Brain oscillations and BIS/BAS (behavioural inhibition/activation system) effects on processing masked emotional cues. ERS/ERD and coherence measures of alpha band. *International Journal of Psychophysiology*, *74*(2), 158–65. http://doi.org/10.1016/j.ijpsycho.2009.08.006

Balconi, M., & Vanutelli, M. E. (2016). Emotions and BIS/BAS components affect brain activity (ERPs and fNIRS) in observing intra-species and inter-species interactions. *Brain Imaging and*

Behavior, *10*(3), 750–760. http://doi.org/10.1007/s11682-015-9443-z

Balconi, M., Vanutelli, M. E., & Grippa, E. (2017). Resting state and personality component (BIS/BAS) predict the brain activity (EEG and fNIRS measure) in response to emotional cues. *Brain and Behavior*, *7*(5), e00686. http://doi.org/10.1002/brb3.686

Bar-On, R., Tranel, D., Denburg, N. L., & Bechara, A. (2003). Exploring the neurological substrate of emotional and social intelligence. *Brain : A Journal of Neurology*, *126*(Pt 8), 1790–800. http://doi.org/10.1093/brain/awg177

Barger, N., Hanson, K. L., Teffer, K., Schenker-Ahmed, N. M., Katerina, & Semendeferi, K. (2014). Evidence for evolutionary specialization in human limbic structures. *Frontiers in Human Neuroscience*, *8*(May), 1–17. http://doi.org/10.3389/fnhum.2014.00277

Barrett, L. F. (2006). Are Emotions Natural Kinds? *Perspectives on Psychological Science*, *1*(1), 28–58. http://doi.org/10.1111/j.1745-6916.2006.00003.x

Barrett, L. F., & Satpute, A. B. (2013). Large-scale brain networks in affective and social neuroscience: Towards an integrative functional architecture of the brain. *Current Opinion in Neurobiology*, *23*(3), 361–72. http://doi.org/10.1016/j.conb.2012.12.012

Barrós-Loscertales, A., Ventura-Campos, N., Sanjuán-Tomás, A., Belloch, V., Parcet, M.-A., & Ávila, C. (2010). Behavioral activation system modulation on brain activation during appetitive and aversive stimulus processing. *Social Cognitive and Affective Neuroscience*, *5*(1), 18–28. http://doi.org/10.1093/scan/nsq012

Bayer, M., & Schacht, A. (2014). Event-related brain responses to emotional words, pictures, and faces: a cross-domain comparison. *Frontiers in Psychology*, *5*(October), 1–10. http://doi.org/10.3389/fpsyg.2014.01106

Bayliss, A. P., Schuch, S., & Tipper, S. P. (2010). Gaze cueing elicited by emotional faces is influenced by affective context. *Visual Cognition*, *18*(8), 1214–1232. http://doi.org/10.1080/13506285.2010.484657

Beall, P. M., & Herbert, A. M. (2008). The face wins: Stronger automatic processing of affect in facial expressions than words in a modified Stroop task. *Cognition and Emotion*, *22*(8), 1613–1642. http://doi.org/10.1080/02699930801940370

Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. *Cerebral Cortex*, *6*(2), 215–225. http://doi.org/10.1093/cercor/6.2.215

Becker, M. W. (2012). Negative emotional photographs are identified more slowly than positive photographs. *Attention, Perception, & Psychophysics*, *74*(6), 1241–1251. http://doi.org/10.3758/s13414-012-0308-x

Bekhtereva, V., Craddock, M., & Müller, M. M. (2015). Attentional bias to affective faces and complex IAPS images in early visual cortex follows emotional cue extraction. *NeuroImage*, *112*, 254–66. http://doi.org/10.1016/j.neuroimage.2015.03.052

Ben-Haim, M. S., Williams, P., Howard, Z., Mama, Y., Eidels, A., & Algom, D. (2016). The Emotional Stroop Task: Assessing Cognitive Performance under Exposure to Emotional Content. *Journal of Visualized Experiments : JoVE*, (112). http://doi.org/10.3791/53720

Bendall, R. C. A., & Thompson, C. (2015). Emotion has no impact on attention in a change detection flicker task. *Frontiers in Psychology*, *6*, 1592. http://doi.org/10.3389/fpsyg.2015.01592

Beraha, E., Eggers, J., Hindi Attar, C., Gutwinski, S., Schlagenhauf, F., Stoy, M., … Bermpohl, F. (2012). Hemispheric Asymmetry for Affective Stimulus Processing in Healthy Subjects–A fMRI Study. *PloS One*, *7*(10), e46931. http://doi.org/10.1371/journal.pone.0046931

Berggren, N., Koster, E. H. W., & Derakshan, N. (2012). The effect of cognitive load in emotional attention and trait anxiety: An eye movement study. *Journal of Cognitive Psychology*, *24*(1), 79–91. http://doi.org/10.1080/20445911.2011.618450

Berkman, E. T., & Lieberman, M. D. (2010). Approaching the bad and avoiding the good: lateral prefrontal cortical asymmetry distinguishes between action and valence. *Journal of Cognitive Neuroscience*, *22*(9), 1970–1979. http://doi.org/10.1162/jocn.2009.21317

Berkman, E. T., Lieberman, M. D., & Gable, S. L. (2009). BIS, BAS, and response conflict: Testing predictions of the revised reinforcement sensitivity theory. *Personality and Individual Differences*, *46*(5–6), 586–591. http://doi.org/10.1016/j.paid.2008.12.015

Berlyne D. E. (1970). Novelty, complexity, and hedonic value. Attention, Perception, & Psychophysics. *Psychonomic Journals*, *8*(5A), 279–286. http://doi.org/10.3758/BF03212593

Blair, K. S. S., Smith, B. W. W., Mitchell, D. G. V. G. V, Morton, J., Vythilingam, M., Pessoa, L., … Blair, R. J. R. J. R. (2007). Modulation of emotion by cognition and cognition by emotion. *NeuroImage*, *35*(1), 430–440. http://doi.org/10.1016/j.neuroimage.2006.11.048

Bonin, T., & Smilek, D. (2016). Inharmonic music elicits more negative affect and interferes more with a concurrent cognitive task than does harmonic music. *Attention, Perception & Psychophysics*, *78*(3), 946–59. http://doi.org/10.3758/s13414-015-1042-y

Bonnefond, M., & Jensen, O. (2012). Alpha Oscillations Serve to Protect Working Memory Maintenance against Anticipated Distracters. *Current Biology*, *22*(20), 1969–1974. http://doi.org/10.1016/j.cub.2012.08.029

Bonnefond, M., & Jensen, O. (2015). Gamma Activity Coupled to Alpha Phase as a Mechanism for Top-Down Controlled Gating. *PLOS ONE*, *10*(6), e0128667. http://doi.org/10.1371/journal.pone.0128667

Borod, J. C., Andelman, F., Obler, L. K., Tweedy, J. R., & Wilkowitz, J. (1992). Right hemisphere specialization for the identification of emotional words and sentences: Evidence from stroke patients. *Neuropsychologia*, *30*(9), 827–844. http://doi.org/10.1016/0028-3932(92)90086-2

Bouman, D., Stins, J. F., & Beek, P. J. (2015). Arousal and exposure duration affect forward step initiation. *Frontiers in Psychology*, *6*, 1667. http://doi.org/10.3389/fpsyg.2015.01667

Boyle, G. J., Matthews, G., & Saklofske, D. H. (2008). The SAGE Handbook of Personality Theory and Assessment: Volume 2 — Personality Measurement and Testing. 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd. http://doi.org/10.4135/9781849200479

Bradley, M. M., Hamby, S., Löw, A., & Lang, P. J. (2007). Brain potentials in perception: Picture complexity and emotional arousal. *Psychophysiology*, *44*(3), 364–373. http://doi.org/10.1111/j.1469-8986.2007.00520.x

Breiter, H. C., Etcoff, N. L., Whalen, P. J., Kennedy, W. a, Rauch, S. L., Buckner, R. L., … Rosen, B. R. (1996). Response and habituation of the human amygdala during visual processing of facial expression. *Neuron*, *17*(5), 875–87. http://doi.org/10.1016/S0896-6273(00)80219-6

Brookshire, G., & Casasanto, D. (2012). Motivation and motor control: Hemispheric specialization for approach motivation reverses with handedness. *PLoS ONE*, *7*(4). http://doi.org/10.1371/journal.pone.0036036

Brunel, N., & Ninio, J. (1997). Time to detect the difference between two images presented side by side. *Cognitive Brain Research*, *5*(4), 273–282. http://doi.org/10.1016/S0926-6410(97)00003-7

Buchner, A., Rothermund, K., Wentura, D., & Mehl, B. (2004). Valence of distractor words increases the effects of irrelevant speech on serial recall. *Memory & Cognition*, *32*(5), 722–31. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15552349

Buhle, J. T., Silvers, J. A., Wage, T. D., Lopez, R., Onyemekwu, C., Kober, H., … Ochsner, K. N. (2014). Cognitive reappraisal of emotion: A meta-analysis of human neuroimaging studies. *Cerebral Cortex*, *24*(11), 2981–2990. http://doi.org/10.1093/cercor/bht154

Bulthe, J., De Smedt, B., & Op De Beeck, H. P. (2015). Visual Number Beats Abstract Numerical Magnitude: Format-dependent Representation of Arabic Digits and Dot Patterns in the Human Parietal Cortex. *Journal of Cognitive Neuroscience*, 1–12. http://doi.org/10.1162/jocn_a_00787

Buratto, L. G., Pottage, C. L., Brown, C., Morrison, C. M., & Schaefer, A. (2014). The effects of a distracting N-back task on

recognition memory are reduced by negative emotional intensity. *PLoS ONE*, *9*(10). http://doi.org/10.1371/journal.pone.0110211

Buzsáki, G., Adey, W. R., Alonso, A., Garcia-Austt, E., Alonso, A., Kohler, C., … Buzsáki, G. (2002). Theta oscillations in the hippocampus. *Neuron*, *33*(3), 325–40. http://doi.org/10.1016/S0896-6273(02)00586-X

Cacioppo, J. T., & Gardner, W. L. (1999). EMOTION. *Annual Review of Psychology*, *50*(1), 191–214. http://doi.org/10.1146/annurev.psych.50.1.191

Calder, A. J., Ewbank, M., & Passamonti, L. (2011). Personality influences the neural responses to viewing facial expressions of emotion. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1571), 1684–1701. http://doi.org/10.1098/rstb.2010.0362

Cappelletti, M., Barth, H., Fregni, F., Spelke, E. S., & Pascual-Leone, A. (2007). rTMS over the intraparietal sulcus disrupts numerosity processing. *Experimental Brain Research*, *179*(4), 631–642. http://doi.org/10.1007/s00221-006-0820-0

Cappelletti, M., Muggleton, N., & Walsh, V. (2009). Quantity without numbers and numbers without quantity in the parietal cortex. *NeuroImage*, *46*(2), 522–529. http://doi.org/10.1016/j.neuroimage.2009.02.016

Caramazza, A. (1996). Pictures, words and the brain. *Nature*, *383*(6597), 216–217. http://doi.org/10.1038/383216a0

Carboni, A., Kessel, D., Capilla, A., & Carretié, L. (2017). The influence of affective state on exogenous attention to emotional distractors: behavioral and electrophysiological correlates. *Scientific Reports*, *7*(1), 8068. http://doi.org/10.1038/s41598-

017-07249-x

Carmon, A., & Nachshon, I. (1973). Ear asymmetry in perception of emotional non-verbal stimuli. *Acta Psychologica*, *37*(6), 351–357. http://doi.org/10.1016/0001-6918(73)90002-4

Carou, I. F., Redondo, J., Piñeiro, A., Padrón, I., Fernández-Rey, J., & Alcaraz, M. (2011). Attentional Processing and Recall of Emotional Words. *Procesamiento Atencional Y Recuerdo de Palabras Emocionales*, *43*(3), 401–418. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=70587601&site=ehost-live

Carr, T. H., McCauley, C., Sperber, R. D., & Parmelee, C. M. (1982). Words, pictures, and priming: on semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology. Human Perception and Performance*, *8*(6), 757–77. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6218234

Carretié, L. (2014). *Exogenous (automatic) attention to emotional stimuli: a review. Cognitive, affective & behavioral neuroscience* (Vol. 14). http://doi.org/10.3758/s13415-014-0270-2

Carretié, L., Hinojosa, J. A., Albert, J., López-Martín, S., De La Gándara, B. S., Igoa, J. M., & Sotillo, M. (2008). Modulation of ongoing cognitive processes by emotionally intense words. *Psychophysiology*, *45*(2), 188–96. http://doi.org/10.1111/j.1469-8986.2007.00617.x

Carretié, L., Hinojosa, J. A., Martín-Loeches, M., Mercado, F., & Tapia, M. (2004). Automatic attention to emotional stimuli: neural correlates. *Human Brain Mapping*, *22*(4), 290–9. http://doi.org/10.1002/hbm.20037

Carretié, L., Kessel, D., Carboni, A., López-Martín, S., Albert, J., Tapia, M., … Hinojosa, J. A. (2013). Exogenous attention to facial vs non-facial emotional visual stimuli. *Social Cognitive and Affective Neuroscience*, *8*(7), 764–73. http://doi.org/10.1093/scan/nss068

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology*, *67*(2), 319–333. http://doi.org/10.1037/0022-3514.67.2.319

Carver, C. S., & White, T. L. (1994). Behavioral Inhibition , Behavioral Activation , and Affective Responses to Impending Reward and Punishment : The BIS / BAS Scales. *Journal of Personality and Social Psychology*, *67*(2), 319–333. http://doi.org/10.1037/0022-3514.67.2.319

Casarotto, S., Ricciardi, E., Romani, S., Dalli, D., & Pietrini, P. (2012). Covert brand recognition engages emotion-specific brain networks. *Archives Italiennes de Biologie*, *150*(4), 259–73. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23479459

Casasanto, D. (2009). Embodiment of abstract concepts: good and bad in right- and left-handers. *Journal of Experimental Psychology. General*, *138*(3), 351–67. http://doi.org/10.1037/a0015854

Caseras, X., ?vila, C., & Torrubia, R. (2003). The measurement of individual differences in Behavioural Inhibition and Behavioural Activation Systems: a comparison of personality scales. *Personality and Individual Differences*, *34*(6), 999–1013. http://doi.org/10.1016/S0191-8869(02)00084-3

Casey, K., Minoshima, S., Berger, K., Koeppe, R., Morrow, T., &

Frey, K. (1994). Positron Emission Tomographic Analysis of Cerebral Structures Activated Specifically by Repetitive Noxious Heat Stimuli. *Journal of Neurophysiology*, *71*(2), 802–7.

Chuah, L. Y. M., Dolcos, F., Chen, A. K., Zheng, H., Parimal, S., & Chee, M. W. L. (2010). Sleep deprivation and interference by emotional distracters. *Sleep*, *33*(10), 1305–1313.

Citron, F. M. M., Abugaber, D., & Herbert, C. (2016). Approach and Withdrawal Tendencies during Written Word Processing: Effects of Task, Emotional Valence, and Emotional Arousal. *Frontiers in Psychology*, *6*. http://doi.org/10.3389/fpsyg.2015.01935

Citron, F. M. M., Weekes, B. S., & Ferstl E. C. (2014). How are affective word ratings related to lexicosemantic properties? Evidence from the Sussex Affective Word List. *Applied Psycholinguistics*, *35*(2), 313–331. http://doi.org/10.1017/S0142716412000409

Coan, J. A., & Allen, J. J. B. (2003). Frontal EEG asymmetry and the behavioral activation and inhibition systems. *Psychophysiology*, *40*(1), 106–114. http://doi.org/10.1111/1469-8986.00011

Coan, J. A., & Allen, J. J. B. (2004). Frontal EEG asymmetry as a moderator and mediator of emotion. *Biological Psychology*, *67*(1–2), 7–49. http://doi.org/10.1016/j.biopsycho.2004.03.002

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 and Behavioral Neuroscience*, 1063–1073. http://doi.org/10.3758/s13415-016-0453-0

Colvin, M. K., Funnell, M. G., & Gazzaniga, M. S. (2005). Numerical

processing in the two hemispheres: Studies of a split-brain patient. *Brain and Cognition*, *57*(1), 43–52. http://doi.org/10.1016/j.bandc.2004.08.019

Comblain, C., D'Argembeau, A., & Van der Linden, M. (2005). Phenomenal characteristics of autobiographical memories for emotional and neutral events in older and younger adults. *Experimental Aging Research*, *31*(2), 173–89. http://doi.org/10.1080/03610730590915010

Compton, R. J. (2000). Ability to disengage attention predicts negative affect. *Cognition & Emotion*, *14*(3), 401–415. http://doi.org/10.1080/026999300378897

Compton, R. J., Banich, M. T., Mohanty, A., Milham, M. P., Herrington, J., Miller, G. A., … Heller, W. (2003). Paying attention to emotion: An fMRI investigation of cognitive and emotional Stroop tasks. *Cognitive, Affective, & Behavioral Neuroscience*, *3*(3), 81–96. http://doi.org/10.3758/CABN.3.2.81

Corr, P. J. (2004). Reinforcement sensitivity theory and personality. *Neuroscience and Biobehavioral Reviews*, *28*(3), 317–32. http://doi.org/10.1016/j.neubiorev.2004.01.005

Corr, P. J. (2008). *The Reinforcement Sensitivity Theory of Personality*. Cambridge University Press.

Corr, P. J. (2013). Approach and Avoidance Behaviour: Multiple Systems and their Interactions. *Emotion Review*, *5*(3), 285–290. http://doi.org/10.1177/1754073913477507

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. Retrieved from

http://www.ncbi.nlm.nih.gov/pubmed/10699350

Cutuli, D. (2014). Cognitive reappraisal and expressive suppression strategies role in the emotion regulation: an overview on their modulatory effects and neural correlates. *Frontiers in Systems Neuroscience*, *8*. http://doi.org/10.3389/fnsys.2014.00175

Cycowicz, Y. M., Friedman, D., Rothstein, M., & Snodgrass, J. G. (1997). Picture Naming by Young Children: Norms for Name Agreement, Familiarity, and Visual Complexity. *Journal of Experimental Child Psychology*, *65*(2), 171–237. http://doi.org/10.1006/jecp.1996.2356

D'Argembeau, A., Comblain, C., & van der Linden, M. (2003). Phenomenal characteristics of autobiographical memories for positive, negative, and neutral events. *Applied Cognitive Psychology*, *17*(3), 281–294. http://doi.org/10.1002/acp.856

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *351*(1346), 1413–1420. http://doi.org/10.1098/rstb.1996.0125

Damasio, A. R., Grabowski, T. J., Bechara, A., Damasio, H., Ponto, L. L., Parvizi, J., & Hichwa, R. D. (2000). Subcortical and cortical brain activity during the feeling of self-generated emotions. *Nature Neuroscience*, *3*(10), 1049–56. http://doi.org/10.1038/79871

Danuser, B., Moser, D., Vitale-Sethre, T., Hirsig, R., & Krueger, H. (2003). Performance in a complex task and breathing under odor exposure. *Human Factors*, *45*(4), 549–62. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15055453

Dastjerdi, M., Ozker, M., Foster, B. L., Rangarajan, V., & Parvizi, J. (2013). Numerical processing in the human parietal cortex during experimental and natural conditions. *Nature Communications*, *4*, 2528. http://doi.org/10.1038/ncomms3528

Davidson, R. J. (1992). Emotion And Affective Style: Hemispheric Substrates. *Psychological Science*, *3*(1), 39–43. http://doi.org/10.1111/j.1467-9280.1992.tb00254.x

Davidson, R. J. (1998). Affective Style and Affective Disorders: Perspectives from Affective Neuroscience. *Cognition & Emotion*, *12*(3), 307–330. http://doi.org/10.1080/026999398379628

Davidson, R.J., & Henriques, J.B. (2000). Regional brain function in sadness and depression. In J. Borod (Ed.) The neuropsychology of emotion (pp. 269–297). New York: Oxford University Press.

Davidson, R., Schwartz, G., Saron, C., Bennett, J., & Goleman, D. (1979). Frontal versus parietal EEG asymmetry during positive and negative affect. *Psychophysiology*, *16*(2), 202–203.

de la Vega, I., de Filippis, M., Lachmair, M., Dudschig, C., & Kaup, B. (2012). Emotional valence and physical space: Limits of interaction. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(2), 375–385. http://doi.org/10.1037/a0024979

De Pascalis, V., Cozzuto, G., Caprara, G. V., & Alessandri, G. (2013). Relations among EEG-alpha asymmetry, BIS/BAS, and dispositional optimism. *Biological Psychology*, *94*(1), 198–209. http://doi.org/10.1016/j.biopsycho.2013.05.016

De Pascalis, V., Varriale, V., & D'Antuono, L. (2010). Event-related components of the punishment and reward sensitivity. *Clinical Neurophysiology : Official Journal of the International*

Federation of Clinical Neurophysiology, *121*(1), 60–76. http://doi.org/10.1016/j.clinph.2009.10.004

Dehaene, S. (1992). Varieties of numerical abilities. *Cognition*, *44*(1–2), 1–42. http://doi.org/10.1016/0010-0277(92)90049-N

Dehaene, S., & Cohen, L. (1995). Towards an anatomical and functional model of number processing. *Mathematical Cognition*. http://doi.org/10.1155/2014/461647

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, *134*(1), 9–21. http://doi.org/10.1016/j.jneumeth.2003.10.009

Delplanque, S., Lavoie, M. E., Hot, P., Silvert, L., & Sequeira, H. (2004). Modulation of cognitive processing by emotional valence studied through event-related potentials in humans. *Neuroscience Letters*, *356*(1), 1–4. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14746887

Demaree, H. A., Robinson, J. L., Everhart, D. E., & Youngstrom, E. A. (2005). Behavioral inhibition system (BIS) strength and trait dominance are associated with affective response and perspective taking when viewing dyadic interactions. *The International Journal of Neuroscience*, *115*(11), 1579–93. http://doi.org/10.1080/00207450590958015

Denkova, E., Wong, G., Dolcos, S., Sung, K., Wang, L., Coupland, N., & Dolcos, F. (2010). The Impact of Anxiety-Inducing Distraction on Cognitive Performance: A Combined Brain Imaging and Personality Investigation. *PLoS ONE*, *5*(11), e14150. http://doi.org/10.1371/journal.pone.0014150

Dickman, S. J. (1990). Functional and dysfunctional impulsivity:

Personality and cognitive correlates. *Journal of Personality and Social Psychology*, *58*(1), 95–102. http://doi.org/10.1037/0022-3514.58.1.95

Diego, M. A., Field, T., & Hernandez-Reif, M. (2001). BIS/BAS scores are correlated with frontal EEG asymmetry in intrusive and withdrawn depressed mothers. *Infant Mental Health Journal*, *22*(6), 665–675. http://doi.org/10.1002/imhj.1025

Doerksen, S., & Shimamura, A. P. (2001). Source memory enhancement for emotional words. *Emotion (Washington, D.C.)*, *1*(1), 5–11. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12894807

Dolcos, F., & Denkova, E. (2014). Current Emotion Research in Cognitive Neuroscience: Linking Enhancing and Impairing Effects of Emotion on Cognition. *Emotion Review*, *6*(4), 362–375. http://doi.org/10.1177/1754073914536449

Dolcos, F., Iordan, A. D., & Dolcos, S. (2011). Neural correlates of emotion–cognition interactions: A review of evidence from brain imaging investigations. *Journal of Cognitive Psychology*, *23*(6), 669–694. http://doi.org/10.1080/20445911.2011.594433

Dolcos, F., Labar, K. S., & Cabeza, R. (2004). Dissociable effects of arousal and valence on prefrontal activity indexing emotional evaluation and subsequent memory: an event-related fMRI study. *NeuroImage*, *23*(1), 64–74. http://doi.org/10.1016/j.neuroimage.2004.05.015

Dolcos, F., & McCarthy, G. (2006). Brain systems mediating cognitive interference by emotional distraction. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *26*(7), 2072–9. http://doi.org/10.1523/JNEUROSCI.5042-05.2006

Dolcos, F., Wang, L., & Mather, M. (2014). Current research and emerging directions in emotion-cognition interactions. *Frontiers in Integrative Neuroscience*, *8*. http://doi.org/10.3389/fnint.2014.00083

Donkin, C., & Nosofsky, R. M. (2012). The structure of short-term memory scanning: an investigation using response time distribution models. *Psychonomic Bulletin & Review*, *19*(3), 363–394. http://doi.org/10.3758/s13423-012-0236-8

Dougal, S., & Rotello, C. M. (2007). "Remembering" emotional words is based on response bias, not recollection. *Psychonomic Bulletin & Review*, *14*(3), 423–9. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17874582

Dreisbach, G. (2006). How positive affect modulates cognitive control: the costs and benefits of reduced maintenance capability. *Brain and Cognition*, *60*(1), 11–9. http://doi.org/10.1016/j.bandc.2005.08.003

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *30*(2), 343–53. http://doi.org/10.1037/0278-7393.30.2.343

Dreyer, F. R., Frey, D., Arana, S., Saldern, S. von, Picht, T., Vajkoczy, P., & Pulvermüller, F. (2015). Is the Motor System Necessary for Processing Action and Abstract Emotion Words? Evidence from Focal Brain Lesions. *Frontiers in Psychology*, *6*. http://doi.org/10.3389/fpsyg.2015.01661

Druzgal, T. J., & D'Esposito, M. (2001). A neural network reflecting decisions about human faces. *Neuron*, *32*(5), 947–55. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11738037

Eisenman, R. (1967). Complexity-simplicity: I. Preference for symmetry and rejection of complexity. *Psychonomic Science*, *8*(4), 169–170. http://doi.org/10.3758/BF03331603

Ekman, R. (1975). Pictures of Facial Affect. *Emotion*, 1–8. http://doi.org/citeulike-article-id:4270156

Elder, J. H., & Goldberg, R. M. (2002). Ecological statistics of Gestalt laws for the perceptual organization of contours. *Journal of Vision*, *2*(4), 324–53. http://doi.org/10.1167/2.4.5

Esslen, M., Pascual-Marqui, R. D., Hell, D., Kochi, K., & Lehmann, D. (2004). Brain areas and time course of emotional processing. *NeuroImage*, *21*(4), 1189–1203. http://doi.org/10.1016/j.neuroimage.2003.10.001

Estes, Z., & Adelman, J. S. (2008). Automatic vigilance for negative words in lexical decision and naming: comment on Larsen, Mercer, and Balota (2006). *Emotion (Washington, D.C.)*, *8*(4), 441-4-57. http://doi.org/10.1037/1528-3542.8.4.441

Eysenck, H. J. (1963). Biological Basis of Personality. *Nature*, *199*(4898), 1031–1034. http://doi.org/10.1038/1991031a0

Eysenck, H. J., & Eysenck, M. W. (1985). *Personality and Individual Differences - A Natural Science Approach*.

Eysenck, H. J., & Eysenck, S. B. G. (1975). *Manual of the Eysenck personality questionnaire*. *Journal of Personality Assessment* (Vol. 43). http://doi.org/10.1177/014662168000400106

Eysenck, H. J., & Eysenck, S. B. G. (1994). Manual for the Eysenck Personality Questionnaire. *(EPQ-R Adult)*, 21. http://doi.org/10.1177/014662168000400106

Fales, C. L., Becerril, K. E., Luking, K. R., & Barch, D. M. (2010).

Emotional-stimulus processing in trait anxiety is modulated by stimulus valence during neuroimaging of a working-memory task. *Cognition & Emotion*, *24*(2), 200–222. http://doi.org/10.1080/02699930903384691

Fernandes, M. A., Koji, S., Dixon, M. J., & Aquino, J. M. (2011). Changing the focus of attention: The interacting effect of valence and arousal. *Visual Cognition*, *19*(9), 1191–1211. http://doi.org/10.1080/13506285.2011.618151

Fernández-Rey, J., & Redondo, J. (2007). Recognition memory for pictorial stimuli: Biasing effects of stimulus emotionality. *Psicothema*.

Ferré, P., Fraga, I., Comesaña, M., & Sánchez-Casas, R. (2015). Memory for emotional words: The role of semantic relatedness, encoding task and affective valence. *Cognition and Emotion*, *29*(8), 1401–1410. http://doi.org/10.1080/02699931.2014.982515

Flaisch, T., Imhof, M., Schmälzle, R., Wentz, K.-U. U., Ibach, B., & Schupp, H. T. (2015). Implicit and Explicit Attention to Pictures and Words: An fMRI-Study of Concurrent Emotional Stimulus Processing. *Frontiers in Psychology*, *6*(DEC). http://doi.org/10.3389/fpsyg.2015.01861

Folta-Schoofs, K., Wolf, O. T., Treue, S., & Schoofs, D. (2014). Perceptual complexity, rather than valence or arousal accounts for distracter-induced overproductions of temporal durations. *Acta Psychologica*, *147*, 51–59. http://doi.org/10.1016/j.actpsy.2013.10.001

Forsythe, A. (2009). Visual Complexity: Is That All There Is? *Complexity*, *5639*, 158–166. http://doi.org/10.1007/978-3-642-02728-4_17

Fox, E., Yates, A., & Ashwin, C. (2012). Trait anxiety and perceptual load as determinants of emotion processing in a fear conditioning paradigm. *Emotion*, *12*(2), 236–249. http://doi.org/10.1037/a0025321

Fox, N. A., & Davidson, R. J. (1986). Taste-elicited changes in facial signs of emotion and the asymmetry of brain electrical activity in human newborns. *Neuropsychologia*, *24*(3), 417–22. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3736825

Frank, D. W., Dewitt, M., Hudgens-Haney, M., Schaeffer, D. J., Ball, B. H., Schwarz, N. F., … Sabatinelli, D. (2014). Emotion regulation: Quantitative meta-analysis of functional activation and deactivation. *Neuroscience & Biobehavioral Reviews*, *45*, 202–211. http://doi.org/10.1016/j.neubiorev.2014.06.010

Frewen, P. A., Dozois, D. J. A., Joanisse, M. F., & Neufeld, R. W. J. (2008). Selective attention to threat versus reward: meta-analysis and neural-network modeling of the dot-probe task. *Clinical Psychology Review*, *28*(2), 307–37. http://doi.org/10.1016/j.cpr.2007.05.006

Frings, C., Amendt, A., & Spence, C. (2011). When seeing doesn't matter: Assessing the after-effects of tactile distractor processing in the blind and the sighted. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(4), 1174–1181. http://doi.org/10.1037/a0022336

Fuster, J. M. (1997). Network memory. *Trends in Neurosciences*, *20*(10), 451–459. http://doi.org/10.1016/S0166-2236(97)01128-4

Gable, P. A., & Harmon-Jones, E. (2013). Trait behavioral approach sensitivity (BAS) relates to early (<150 ms) electrocortical responses to appetitive stimuli. *Social Cognitive and Affective Neuroscience*, *8*(7), 795–798.

http://doi.org/10.1093/scan/nss072

Gable, P. A., & Poole, B. D. (2014). Influence of trait behavioral inhibition and behavioral approach motivation systems on the LPP and frontal asymmetry to anger pictures. *Social Cognitive and Affective Neuroscience*, *9*(2), 182–190. http://doi.org/10.1093/scan/nss130

Gaeta, G., Susac, A., Supek, S., Babiloni, F., & Vecchiato, G. (2015). Analysis of EEG variables to measure the affective dimensions of arousal and valence related to the vision of emotional pictures. *Conference Proceedings : Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference*, *2015*, 2518–21. http://doi.org/10.1109/EMBC.2015.7318904

Gasquoine, P. G. (2013). Localization of function in anterior cingulate cortex: From psychosurgery to functional neuroimaging. *Neuroscience and Biobehavioral Reviews*, *37*(3), 340–348. http://doi.org/10.1016/j.neubiorev.2013.01.002

George, M. S., Ketter, T. A., Parekh, P. I., Horwitz, B., Herscovitch, P., & Post, R. M. (1995). Brain activity during transient sadness and happiness in healthy women. *The American Journal of Psychiatry*, *152*(3), 341–51. http://doi.org/10.1176/ajp.152.3.341

Gevins, A., Smith, M. E., McEvoy, L., & Yu, D. (1997). High-resolution EEG mapping of cortical activation related to working memory: effects of task difficulty, type of processing, and practice. *Cerebral Cortex (New York, N.Y. : 1991)*, *7*(4), 374–85. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9177767

Gilboa-Schechtman, E., Foa, E. B., & Amir, N. (1999). Attentional

Biases for Facial Expressions in Social Phobia: The Face-in-the-Crowd Paradigm. *Cognition & Emotion*, *13*(3), 305–318. http://doi.org/10.1080/026999399379294

Gladwin, T. E., den Uyl, T. E., Fregni, F. F., & Wiers, R. W. (2012). Enhancement of selective attention by tDCS: Interaction with interference in a Sternberg task. *Neuroscience Letters*, *512*(1), 33–37. http://doi.org/10.1016/j.neulet.2012.01.056

Gläscher, J., & Adolphs, R. (2003). Processing of the arousal of subliminal and supraliminal emotional stimuli by the human amygdala. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *23*(32), 10274–82. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14614086

Glaser, W. R. (1992). Picture naming. *Cognition*, *42*(1–3), 61–105. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1582161

Goldin, P. R., & Gross, J. J. (2010). Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. *Emotion*, *10*(1), 83–91. http://doi.org/10.1037/a0018441

Goldstein, K. (1939). The organism, a holistic approach to biology. *New York: American Book*.

Gomez, A., & Gomez, R. (2002). Personality traits of the behavioural approach and inhibition systems: associations with processing of emotional stimuli. *Personality and Individual Differences*, *32*(8), 1299–1316. http://doi.org/10.1016/S0191-8869(01)00119-2

Grady, C. L., Mcintosh, A. R., Rajah, M. N., & Craik, F. I. M. (1998). Neural correlates of the episodic encoding of pictures and words. *Proceedings of the National Academy of Sciences*, *95*(5), 2703–2708. http://doi.org/10.1073/pnas.95.5.2703

Gray, J. a. (1987). Perspectives on anxiety and impulsivity: A commentary. *Journal of Research in Personality*, *21*(4), 493–509. http://doi.org/10.1016/0092-6566(87)90036-5

Gray, J. A. (1981). A critique of Eysenck's theory of personality. In *A Model for Personality* (pp. 246–276). http://doi.org/10.1017/S0140525X00061872

Gray, J. A., & McNaughton, N. (1982). *The Neuropsychology of Anxiety*. Oxford University Press. http://doi.org/10.1093/acprof:oso/9780198522713.001.0001

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2*(3), 271–299. http://doi.org/10.1037/1089-2680.2.3.271

Gross, J. J., Sheppes, G., & Urry, H. L. (2011). Cognition and Emotion Lecture at the 2010 SPSP Emotion Preconference. *Cognition & Emotion*, *25*(5), 765–781. http://doi.org/10.1080/02699931.2011.555753

Gruber, T., & Müller, M. M. (2005). Oscillatory brain activity dissociates between associative stimulus content in a repetition priming task in the human EEG. *Cerebral Cortex (New York, N.Y.: 1991)*, *15*(1), 109–16. http://doi.org/10.1093/cercor/bhh113

Güntekin, B., Femir, B., Gölbaşı, B. T., Tülay, E., & Başar, E. (2017). Affective pictures processing is reflected by an increased long-distance EEG connectivity. *Cognitive Neurodynamics*, *11*(4), 355–367. http://doi.org/10.1007/s11571-017-9439-z

Gupta, R., Hur, Y.-J., & Lavie, N. (2016). Distracted by pleasure: Effects of positive versus negative valence on emotional capture under load. *Emotion (Washington, D.C.)*, *16*(3), 328–

37. http://doi.org/10.1037/emo0000112

Habeck, C., Rakitin, B. C., Moeller, J., Scarmeas, N., Zarahn, E., Brown, T., & Stern, Y. (2005). An event-related fMRI study of the neural networks underlying the encoding, maintenance, and retrieval phase in a delayed-match-to-sample task. *Brain Research. Cognitive Brain Research*, *23*(2–3), 207–20. http://doi.org/10.1016/j.cogbrainres.2004.10.010

Habeck, C., Rakitin, B., Steffener, J., & Stern, Y. (2012). Contrasting visual working memory for verbal and non-verbal material with multivariate analysis of fMRI. *Brain Research*, *1467*, 27–41. http://doi.org/10.1016/j.brainres.2012.05.045

Hajcak, G., Dunning, J. P., & Foti, D. (2007). Neural response to emotional pictures is unaffected by concurrent task difficulty: an event-related potential study. *Behavioral Neuroscience*, *121*(6), 1156–62. http://doi.org/10.1037/0735-7044.121.6.1156

Hardie, S. M., & Wright, L. (2014). Differences between left- and right-handers in approach/avoidance motivation: Influence of consistency of handedness measures. *Frontiers in Psychology*, *5*(FEB), 1–10. http://doi.org/10.3389/fpsyg.2014.00134

Harlow, J. M. (1993). Recovery from the passage of an iron bar through the head. *History of Psychiatry*, *4*(14), 274–281. http://doi.org/10.1177/0957154X9300401407

Harmon-Jones, E., & Allen, J. J. (1997). Behavioral activation sensitivity and resting frontal EEG asymmetry: covariation of putative indicators related to risk for mood disorders. *Journal of Abnormal Psychology*, *106*(1), 159–163. http://doi.org/10.1037/0021-843X.106.1.159

Harmon-Jones, E., & Allen, J. J. (1998). Anger and frontal brain

activity: EEG asymmetry consistent with approach motivation despite negative affective valence. *Journal of Personality and Social Psychology*, *74*(5), 1310–6. http://doi.org/10.1037/0022-3514.74.5.1310

Harmon-Jones, E., Gable, P. a., & Peterson, C. K. (2010). The role of asymmetric frontal cortical activity in emotion-related phenomena: A review and update. *Biological Psychology*, *84*(3), 451–462. http://doi.org/10.1016/j.biopsycho.2009.08.010

Heimer, L., & Van Hoesen, G. W. (2006). The limbic lobe and its output channels: Implications for emotional functions and adaptive behavior. *Neuroscience & Biobehavioral Reviews*, *30*(2), 126–147. http://doi.org/10.1016/j.neubiorev.2005.06.006

Hellige, J. B. (1993). *Hemispheric asymmetry. What's right and what's left*. *Perspectives in cognitive neuroscience*. http://doi.org/10.1016/0166-2236(93)90012-B

Henson, R. N., Rugg, M. D., Shallice, T., & Dolan, R. J. (2000). Confidence in recognition memory for words: dissociating right prefrontal roles in episodic retrieval. *Journal of Cognitive Neuroscience*, *12*(6), 913–23. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11177413

Henson, R. N., Rugg, M. D., Shallice, T., Josephs, O., & Dolan, R. J. (1999). Recollection and familiarity in recognition memory: an event-related functional magnetic resonance imaging study. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *19*(10), 3962–72. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10234026

Herbert, C., Junghofer, M., & Kissler, J. (2008). Event related potentials to emotional adjectives during reading.

Psychophysiology, *45*(3), 487–98. http://doi.org/10.1111/j.1469-8986.2007.00638.x

Herrington, J. D., Mohanty, A., Koven, N. S., Fisher, J. E., Stewart, J. L., Banich, M. T., … Heller, W. (2005). Emotion-Modulated Performance and Activity in Left Dorsolateral Prefrontal Cortex. *Emotion*, *5*(2), 200–207. http://doi.org/10.1037/1528-3542.5.2.200

Hindi Attar, C., Andersen, S. K., & Müller, M. M. (2010). Time course of affective bias in visual attention: Convergent evidence from steady-state visual evoked potentials and behavioral data. *NeuroImage*, *53*(4), 1326–1333. http://doi.org/10.1016/j.neuroimage.2010.06.074

Hindi Attar, C., & Müller, M. M. (2012). Selective attention to task-irrelevant emotional distractors is unaffected by the perceptual load associated with a foreground task. *PloS One*, *7*(5), e37186. http://doi.org/10.1371/journal.pone.0037186

Hinojosa, J. A., Carretié, L., Valcárcel, M. A., Méndez-Bértolo, C., & Pozo, M. A. (2009). Electrophysiological differences in the processing of affective information in words and pictures. *Cognitive, Affective, & Behavioral Neuroscience*, *9*(2), 173–189. http://doi.org/10.3758/CABN.9.2.173

Hinojosa, J. A., Mercado, F., Albert, J., Barjola, P., Peláez, I., Villalba-García, C., & Carretié, L. (2015). Neural correlates of an early attentional capture by positive distractor words. *Frontiers in Psychology*, *6*, 24. http://doi.org/10.3389/fpsyg.2015.00024

Ho, C., & Spence, C. (2005). Olfactory facilitation of dual-task performance. *Neuroscience Letters*, *389*(1), 35–40. http://doi.org/10.1016/j.neulet.2005.07.003

Hodsoll, S., Viding, E., & Lavie, N. (2011). Attentional capture by irrelevant emotional distractor faces. *Emotion*, *11*(2), 346–353. http://doi.org/10.1037/a0022771

Hoorelbeke, K., Koster, E. H. W., Demeyer, I., Loeys, T., & Vanderhasselt, M.-A. (2016). Effects of cognitive control training on the dynamics of (mal)adaptive emotion regulation in daily life. *Emotion (Washington, D.C.)*, *16*(7), 945–956. http://doi.org/10.1037/emo0000169

Houwer, J. De, & Hermans, D. (1994). Differences in the affective processing of words and pictures. *Cognition & Emotion*, *8*(1), 1–20. http://doi.org/10.1080/02699939408408925

Ihssen, N., Heim, S., & Keil, A. (2007). The Costs of Emotional Attention: Affective Processing Inhibits Subsequent Lexico-semantic Analysis. *Journal of Cognitive Neuroscience*, *19*(12), 1932–1949. http://doi.org/10.1162/jocn.2007.19.12.1932

Inzlicht, M., Bartholow, B. D., & Hirsh, J. B. (2015). Emotional foundations of cognitive control. *Trends in Cognitive Sciences*, *19*(3), 126–132. http://doi.org/10.1016/j.tics.2015.01.004

Iordan, A. D., & Dolcos, F. (2015). Brain Activity and Network Interactions Linked to Valence-Related Differences in the Impact of Emotional Distraction. *Cerebral Cortex*, (January), bhv242. http://doi.org/10.1093/cercor/bhv242

Itkes, O., Kimchi, R., Haj-Ali, H., Shapiro, A., & Kron, A. (2017). Dissociating affective and semantic valence. *Journal of Experimental Psychology: General*, *146*(7), 924–942. http://doi.org/10.1037/xge0000291

Izard, C. E. (2007). Basic Emotions, Natural Kinds, Emotion Schemas, and a New Paradigm. *Perspectives on Psychological Science*, *2*(3), 260–280. http://doi.org/10.1111/j.1745-

6916.2007.00044.x

Izard, C. E. (2009). Emotion Theory and Research: Highlights, Unanswered Questions, and Emerging Issues. *Annual Review of Psychology*, *60*, 1–25. http://doi.org/10.1146/annurev.psych.60.110707.163539.Emotion

Izard, C. E. (2010). The Many Meanings/Aspects of Emotion: Definitions, Functions, Activation, and Regulation. *Emotion Review*, *2*(4), 363–370. http://doi.org/10.1177/1754073910374661

Jackson, D. C., Mueller, C. J., Dolski, I., Dalton, K. M., Nitschke, J. B., Urry, H. L., … Davidson, R. J. (2012). Now You Feel It, Now You Don't: Frontal Brain Electrical Asymmetry and Individual Differences in Emotion Regulation, *14*(6), 612–617.

Jackson, M. C., Linden, D. E. J., & Raymond, J. E. (2012). "Distracters" Do Not Always Distract: Visual Working Memory for Angry Faces is Enhanced by Incidental Emotional Words. *Frontiers in Psychology*, *3*(OCT), 1–9. http://doi.org/10.3389/fpsyg.2012.00437

Jacobsen, T., Schubotz, R. I., Höfel, L., & Cramon, D. Y. v. (2006). Brain correlates of aesthetic judgment of beauty. *NeuroImage*, *29*(1), 276–285. http://doi.org/10.1016/j.neuroimage.2005.07.010

Jensen, O., & Tesche, C. D. (2002). Frontal theta activity in humans increases with memory load in a working memory task. *The European Journal of Neuroscience*, *15*(8), 1395–9. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11994134

Jung, T.-P., Humphries, C., Lee, T.-W., Makeig, S., McKeown, M.

J., Iragui, V., & Sejnowski, T. J. (1998). Extended ICA removes artifacts from electroencephalographic recordings. *Advances in Neural Information Processing Systems*, *10*, 894–900.

Kappas, a. (2011). Emotion and Regulation are One! *Emotion Review*, *3*(1), 17–25. http://doi.org/10.1177/1754073910380971

Kauffman, K. P. (2015). Emotional sentience and the nature of phenomenal experience. *Progress in Biophysics and Molecular Biology*, *119*(3), 545–562. http://doi.org/10.1016/j.pbiomolbio.2015.08.003

Keil, A. (2006). Macroscopic brain dynamics during verbal and pictorial processing of affective stimuli. *Progress in Brain Research*, *156*, 217–32. http://doi.org/10.1016/S0079-6123(06)56011-X

Keil, A., Bradley, M. M., Hauk, O., Rockstroh, B., Elbert, T., & Lang, P. J. (2002). Large-scale neural correlates of affective picture processing. *Psychophysiology*, *39*(5), 641–9. http://doi.org/10.1017.S0048577202394162

Keil, A., Moratti, S., Sabatinelli, D., Bradley, M. M., & Lang, P. J. (2005). Additive Effects of Emotional Content and Spatial Selective Attention on Electrocortical Facilitation. *Cerebral Cortex*, *15*(8), 1187–1197. http://doi.org/10.1093/cercor/bhi001

Kellermann, T. S., Sternkopf, M. A., Schneider, F., Habel, U., Turetsky, B. I., Zilles, K., & Eickhoff, S. B. (2012). Modulating the processing of emotional stimuli by cognitive demand. *Social Cognitive and Affective Neuroscience*, *7*(3), 263–273. http://doi.org/10.1093/scan/nsq104

Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional

pictures and words: Effects of valence and arousal. *Cognitive, Affective & Behavioral Neuroscience*, *6*(2), 110–126. http://doi.org/10.3758/CABN.6.2.110

Khateb, A., Pegna, A. J., Michel, C. M., Landis, T., & Annoni, J.-M. (2002). Dynamics of brain activation during an explicit word and image recognition task: an electrophysiological study. *Brain Topography*, *14*(3), 197–213. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12002350

Kim, S. H., Yoon, H., Kim, H., & Hamann, S. (2015). Individual differences in sensitivity to reward and punishment and neural activity during reward and avoidance learning. *Social Cognitive and Affective Neuroscience*, *10*(9), 1219–1227. http://doi.org/10.1093/scan/nsv007

Kinnison, J., Padmala, S., Choi, J.-M., & Pessoa, L. (2012). Network analysis reveals increased integration during emotional and motivational processing. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *32*(24), 8361–72. http://doi.org/10.1523/JNEUROSCI.0821-12.2012

Kirschen, M. P., Chen, S. H. A., Schraedley-Desmond, P., & Desmond, J. E. (2005). Load- and practice-dependent increases in cerebro-cerebellar activation in verbal working memory: an fMRI study. *NeuroImage*, *24*(2), 462–472. http://doi.org/10.1016/j.neuroimage.2004.08.036

Kissler, J., Herbert, C., Winkler, I., & Junghofer, M. (2009). Emotion and attention in visual word processing: an ERP study. *Biological Psychology*, *80*(1), 75–83. http://doi.org/10.1016/j.biopsycho.2008.03.004

Kleinginna, P. R., & Kleinginna, A. M. (1981). A categorized list of motivation definitions, with a suggestion for a consensual

definition. *Motivation and Emotion*, *5*(3), 263–291. http://doi.org/10.1007/BF00993889

Klimesch, W., Doppelmayr, M., Stadler, W., Pöllhuber, D., Sauseng, P., & Röhm, D. (2001). Episodic retrieval is reflected by a process specific increase in human electroencephalographic theta activity. *Neuroscience Letters*, *302*(1), 49–52. http://doi.org/10.1016/S0304-3940(01)01656-1

Kober, H., Barrett, L. F., Joseph, J., Bliss-Moreau, E., Lindquist, K., & Wager, T. D. (2008). Functional grouping and cortical–subcortical interactions in emotion: A meta-analysis of neuroimaging studies. *NeuroImage*, *42*(2), 998–1031. http://doi.org/10.1016/j.neuroimage.2008.03.059

Kohler, S., Moscovitch, M., Winocur, G., & McIntosh, A. R. (2000). Episodic encoding and recognition of pictures and words: role of the human medial temporal lobes. *Acta Psychologica*, *105*(2–3), 159–179. http://doi.org/10.1016/S0001-6918(00)00059-7

Kosonogov, V., Sanchez-Navarro, J. P., Martinez-Selva, J. M., Torrente, G., & Carrillo-Verdejo, E. (2016). Social stimuli increase physiological reactivity but not defensive responses. *Scandinavian Journal of Psychology*, *57*(5), 393–398. http://doi.org/10.1111/sjop.12311

Kousta, S.-T., Vinson, D. P., & Vigliocco, G. (2009). Emotion words, regardless of polarity, have a processing advantage over neutral words. *Cognition*, *112*(3), 473–481. http://doi.org/10.1016/j.cognition.2009.06.007

Krpan, D., & Schnall, S. (2014). Too close for comfort: Stimulus valence moderates the influence of motivational orientation on distance perception. *Journal of Personality and Social Psychology*, *107*(6), 978–93.

http://doi.org/10.1037/pspa0000017

Kuchinke, L., Jacobs, A. M., Võ, M. L.-H., Conrad, M., Grubich, C., & Herrmann, M. (2006). Modulation of prefrontal cortex activation by emotional words in recognition memory. *Neuroreport*, *17*(10), 1037–1041. http://doi.org/10.1097/01.wnr.0000221838.27879.fe

Kugurakova, V., Talanov, M., Manakhov, N., & Ivanov, D. (2015). Anthropomorphic Artificial Social Agent with Simulated Emotions and its Implementation. *Procedia Computer Science*, *71*, 112–118. http://doi.org/10.1016/j.procs.2015.12.217

Kuperman, V., Estes, Z., Brysbaert, M., & Warriner, A. B. (2014). Emotion and language: Valence and arousal affect word recognition. *Journal of Experimental Psychology: General*, *143*(3), 1065–1081. http://doi.org/10.1037/a0035669

LaBar, K. S., & Cabeza, R. (2006). Cognitive neuroscience of emotional memory. *Nature Reviews Neuroscience*, *7*(1), 54–64. http://doi.org/10.1038/nrn1825

Lane, R. D., Chua, P. M. L., & Dolan, R. J. (1999). Common effects of emotional valence, arousal and attention on neural activation during visual processing of pictures. *Neuropsychologia*, *37*(9), 989–997. http://doi.org/10.1016/S0028-3932(99)00017-2

Lang, P. . J. ., Bradley, M. . M. ., & Cuthbert, B. . N. . (2008a). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8.* Retrieved from ftp://dhcp-129-105-171-164.psych.northwestern.edu/OpenShare/ESPN/IAPS 1-16/IAPS 1-16/IAPSmanual.pdf

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008b). *International affective picture system (IAPS): Instruction*

manual and affective ratings. Technical Report A-8. Retrieved from ftp://dhcp-129-105-171-164.psych.northwestern.edu/OpenShare/ESPN/IAPS 1-16/IAPS 1-16/IAPSmanual.pdf

Lavie, N. (2005). Distracted and confused?: selective attention under load. *Trends in Cognitive Sciences*, *9*(2), 75–82. http://doi.org/10.1016/j.tics.2004.12.004

Leclerc, C. M., & Kensinger, E. A. (2011). Neural Processing of Emotional Pictures and Words: A Comparison of Young and Older Adults. *Developmental Neuropsychology*, *36*(4), 519–538. http://doi.org/10.1080/87565641.2010.549864

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, *23*, 155–84. http://doi.org/10.1146/annurev.neuro.23.1.155

Lichtenstein-Vidne, L., Henik, A., & Safadi, Z. (2007). Task-relevance modulates the effects of peripheral distractors. *The Quarterly Journal of Experimental Psychology*, *60*(9), 1216–1226. http://doi.org/10.1080/17470210600917892

Lim, S.-L., Bruce, A. S., & Aupperle, R. L. (2014). The Influence of a Working Memory Task on Affective Perception of Facial Expressions. *PLoS ONE*, *9*(10), e111074. http://doi.org/10.1371/journal.pone.0111074

Liu, B., Jin, Z., Wang, Z., & Hu, Y. (2010). The interaction between pictures and words: evidence from positivity offset and negativity bias. *Experimental Brain Research*, *201*(2), 141–53. http://doi.org/10.1007/s00221-009-2018-8

Logie, R. H., Zucco, G. M., & Baddeley, A. D. (1990). Interference with visual short-term memory. *Acta Psychologica*, *75*(1), 55–74. Retrieved from

http://www.ncbi.nlm.nih.gov/pubmed/2260493

Long, N. M., Danoff, M. S., & Kahana, M. J. (2015). Recall dynamics reveal the retrieval of emotional context. *Psychonomic Bulletin & Review*, *22*(5), 1328–1333. http://doi.org/10.3758/s13423-014-0791-2

Lövheim, H. (2012). A new three-dimensional model for emotions and monoamine neurotransmitters. *Medical Hypotheses*, *78*(2), 341–348. http://doi.org/10.1016/j.mehy.2011.11.016

MacLean, P. D. (1952). Some psychiatric implications of physiological studies on frontotemporal portion of limbic system (visceral brain). *Electroencephalography and Clinical Neurophysiology*, *4*(4), 407–418. http://doi.org/10.1016/0013-4694(52)90073-4

MacLEAN, P. D. (1949). Psychosomatic disease and the visceral brain; recent developments bearing on the Papez theory of emotion. *Psychosomatic Medicine*, *11*(6), 338–353. http://doi.org/10.1097/00006842-194911000-00003

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychological Bulletin*, *109*(2), 163–203. http://doi.org/Doi 10.1037//0033-2909.109.2.163

Maddox, G. B., Naveh-Benjamin, M., Old, S., & Kilb, A. (2012). The role of attention in the associative binding of emotionally arousing words. *Psychonomic Bulletin & Review*, *19*(6), 1128–1134. http://doi.org/10.3758/s13423-012-0315-x

Madill, M., & Murray, J. E. (2017). Processing Distracting Non-face Emotional Images: No Evidence of an Age-Related Positivity Effect. *Frontiers in Psychology*, *8*(April), 1–12. http://doi.org/10.3389/fpsyg.2017.00591

Marchewka, A., Wypych, M., Moslehi, A., Riegel, M., Michałowski,

J. M., & Jednoróg, K. (2016). Arousal Rather than Basic Emotions Influence Long-Term Recognition Memory in Humans. *Frontiers in Behavioral Neuroscience*, *10*. http://doi.org/10.3389/fnbeh.2016.00198

Marchewka, A., Żurawski, Ł., Jednoróg, K., & Grabowska, A. (2014). The Nencki Affective Picture System (NAPS): Introduction to a novel, standardized, wide-range, high-quality, realistic picture database. *Behavior Research Methods*, *46*(2), 596–610. http://doi.org/10.3758/s13428-013-0379-1

Masuda, N. (2015). Effects of emotional valence (positive or negative visual images) and arousal levels (high or low arousal levels) on the useful field of view. *Psychology*. http://doi.org/10.4236/psych.2015.64045

Matthews, G., & Gilliland, K. (1999). The personality theories of H.J. Eysenck and J.A. Gray: a comparative review. *Personality and Individual Differences*, *26*(4), 583–626. http://doi.org/10.1016/S0191-8869(98)00158-5

Matthys, W., van Goozen, S. H., de Vries, H., Cohen-Kettenis, P. T., & van Engeland, H. (1998). The dominance of behavioural activation over behavioural inhibition in conduct disordered boys with or without attention deficit hyperactivity disorder. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *39*(5), 643–51. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9690928

Mavratzakis, A., Herbert, C., & Walla, P. (2016). Emotional facial expressions evoke faster orienting responses, but weaker emotional responses at neural and behavioural levels compared to scenes: A simultaneous EEG and facial EMG study. *NeuroImage*, *124*, 931–946. http://doi.org/10.1016/j.neuroimage.2015.09.065

McGaugh, J. L. (2013). Making lasting memories: Remembering the significant. *Proceedings of the National Academy of Sciences*, *110*(Supplement_2), 10402–10407. http://doi.org/10.1073/pnas.1301209110

McKenna, F. P., & Sharma, D. (1995). Intrusive cognitions: An investigation of the emotional Stroop task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(6), 1595–1607. http://doi.org/10.1037/0278-7393.21.6.1595

McNaughton, N., & Gray, J. A. (2000). Anxiolytic action on the behavioural inhibition system implies multiple types of arousal contribute to anxiety. *Journal of Affective Disorders*, *61*(3), 161–176. http://doi.org/10.1016/S0165-0327(00)00344-X

McRae, K. (2016). Cognitive emotion regulation: A review of theory and scientific findings. *Current Opinion in Behavioral Sciences*, *10*, 119–124. http://doi.org/10.1016/j.cobeha.2016.06.004

Mehrabian, A. (1996). Pleasure-arousal-dominance: A general framework for describing and measuring individual differences in Temperament. *Current Psychology*, *14*(4), 261–292. http://doi.org/10.1007/BF02686918

Méndez-Bértolo, C., Moratti, S., Toledano, R., Lopez-Sosa, F., Martínez-Alvarez, R., Mah, Y. H., … Strange, B. A. (2016). A fast pathway for fear in human amygdala. *Nature Neuroscience*, *19*(8), 1041–1049. http://doi.org/10.1038/nn.4324

Milhau, A., Brouillet, T., & Brouillet, D. (2015). Valence–space compatibility effects depend on situated motor fluency in both right- and left-handers. *The Quarterly Journal of Experimental Psychology*, *68*(5), 887–899.

http://doi.org/10.1080/17470218.2014.967256

Miller, G. A., Crocker, L. D., Spielberg, J. M., Infantolino, Z. P., & Heller, W. (2013). Issues in localization of brain function: The case of lateralized frontal cortex in cognition, emotion, and psychopathology. *Frontiers in Integrative Neuroscience*, *7*, 2. http://doi.org/10.3389/fnint.2013.00002

Mogg, K., McNamara, J., Powys, M., Rawlinson, H., Seiffer, A., & Bradley, B. P. (2000). Selective attention to threat: A test of two cognitive models of anxiety. *Cognition & Emotion*, *14*(3), 375–399. http://doi.org/10.1080/026999300378888

Molko, N., Cachia, A., Rivière, D., Mangin, J. F., Bruandet, M., Le Bihan, D., … Dehaene, S. (2003). Functional and structural alterations of the intraparietal sulcus in a developmental dyscalculia of genetic origin. *Neuron*, *40*(4), 847–858. http://doi.org/10.1016/S0896-6273(03)00670-6

Möller, M., Mayr, S., & Buchner, A. (2015). The time-course of distractor processing in auditory spatial negative priming. *Psychological Research*. http://doi.org/10.1007/s00426-015-0685-6

Morgane, P. J., Galler, J. R., & Mokler, D. J. (2005). A review of systems and networks of the limbic forebrain/limbic midbrain. *Progress in Neurobiology*, *75*(2), 143–160. http://doi.org/10.1016/j.pneurobio.2005.01.001

Moriguchi, Y., Negreira, A., Weierich, M., Dautoff, R., Dickerson, B. C., Wright, C. I., & Barrett, L. F. (2011). Differential hemodynamic response in affective circuitry with aging: an FMRI study of novelty, valence, and arousal. *Journal of Cognitive Neuroscience*, *23*(5), 1027–41. http://doi.org/10.1162/jocn.2010.21527

Moseley, R., Carota, F., Hauk, O., Mohr, B., & Pulvermuller, F. (2012). A Role for the Motor System in Binding Abstract Emotional Meaning. *Cerebral Cortex*, *22*(7), 1634–1647. http://doi.org/10.1093/cercor/bhr238

Most, S. B., Chun, M. M., Widders, D. M., & Zald, D. H. (2005). Attentional rubbernecking: cognitive control and personality in emotion-induced blindness. *Psychonomic Bulletin & Review*, *12*(4), 654–61. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16447378

Moyal, N., Henik, A., & Anholt, G. E. (2014). Cognitive strategies to regulate emotions-current evidence and future directions. *Frontiers in Psychology*, *4*(JAN), 1–4. http://doi.org/10.3389/fpsyg.2013.01019

Mulej Bratec, S., Xie, X., Schmid, G., Doll, A., Schilbach, L., Zimmer, C., … Sorg, C. (2015). Cognitive emotion regulation enhances aversive prediction error activity while reducing emotional responses. *NeuroImage*, *123*, 138–48. http://doi.org/10.1016/j.neuroimage.2015.08.038

Muller, M. M., Andersen, S. K., & Hindi Attar, C. (2011). Attentional Bias to Briefly Presented Emotional Distractors Follows a Slow Time Course in Visual Cortex. *Journal of Neuroscience*, *31*(44), 15914–15918. http://doi.org/10.1523/JNEUROSCI.1997-11.2011

Muller, M. M., Andersen, S. K., & Keil, A. (2008). Time Course of Competition for Visual Processing Resources between Emotional Pictures and Foreground Task. *Cerebral Cortex*, *18*(8), 1892–1899. http://doi.org/10.1093/cercor/bhm215

Müller, M. M., & Gundlach, C. (2017). Competition for attentional resources between low spatial frequency content of emotional images and a foreground task in early visual cortex.

Psychophysiology, *54*(3), 429–443. http://doi.org/10.1111/psyp.12792

Murty, V. P., Ritchey, M., Adcock, R. A., & LaBar, K. S. (2011). Reprint of: fMRI studies of successful emotional memory encoding: A quantitative meta-analysis. *Neuropsychologia*, *49*(4), 695–705. http://doi.org/10.1016/j.neuropsychologia.2011.02.031

Nobata, T., Hakoda, Y., & Ninose, Y. (2010). The functional field of view becomes narrower while viewing negative emotional stimuli. *Cognition & Emotion*, *24*(5), 886–891. http://doi.org/10.1080/02699930902955954

Nolte, G., Bai, O., Wheaton, L., Mari, Z., Vorbach, S., & Hallett, M. (2004). Identifying true brain interaction from EEG data using the imaginary part of coherency. *Clinical Neurophysiology*, *115*(10), 2292–2307. http://doi.org/10.1016/j.clinph.2004.04.029

Notebaert, K., & Reynvoet, B. (2009). Different magnitude representations in left and right hemisphere: Evidence from the visual half field technique. *Laterality: Asymmetries of Body, Brain and Cognition*, *14*(3), 228–245. http://doi.org/10.1080/13576500802349650

Ochsner, K. N. (2000). Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of Experimental Psychology. General*, *129*(2), 242–261. http://doi.org/10.1037/0096-3445.129.2.242

Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. E. (2002). Rethinking Feelings: An fMRI Study of the Cognitive Regulation of Emotion. *Journal of Cognitive Neuroscience*, *14*(8), 1215–1229.

http://doi.org/10.1162/089892902760807212

Ochsner, K. N., & Gross, J. J. (2008). Cognitive Emotion Regulation: Insights From Social Cognitive and Affective Neuroscience. *Current Directions in Psychological Science*, *17*(2), 153–158. http://doi.org/10.1111/j.1467-8721.2008.00566.x

Oei, N. Y. L., Tollenaar, M. S., Elzinga, B. M., & Spinhoven, P. (2010). Propranolol reduces emotional distraction in working memory: A partial mediating role of propranolol-induced cortisol increases? *Neurobiology of Learning and Memory*, *93*(3), 388–395. http://doi.org/10.1016/j.nlm.2009.12.005

Oei, N. Y. L., Veer, I. M., Wolf, O. T., Spinhoven, P., Rombouts, S. A. R. B., & Elzinga, B. M. (2012). Stress shifts brain activation towards ventral "affective" areas during emotional distraction. *Social Cognitive and Affective Neuroscience*, *7*(4), 403–412. http://doi.org/10.1093/scan/nsr024

Ohman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology. General*, *130*(3), 466–78. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11561921

Ohman, A., Hamm, A., & Hugdahl, K. (2000). Cognition and the autonomic nervous system: Orienting, anticipation, and conditioning. In *Handbook of Psychophysiology* (pp. 533–575).

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*(3), 381–96. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11300573

Okon-Singer, H., Hendler, T., Pessoa, L., & Shackman, A. J.

(2015). The neurobiology of emotion and cognition interactions: fundamental questions and strategies for future research. *Frontiers in Human Neuroscience*, *9*. http://doi.org/10.3389/fnhum.2015.00058

Okon-Singer, H., Tzelgov, J., & Henik, A. (2007). Distinguishing between automaticity and attention in the processing of emotionally significant stimuli. *Emotion*, *7*(1), 147–157. http://doi.org/10.1037/1528-3542.7.1.147

Okuhata, S., Kusanagi, T., Kawaguchi, H., & Kobayashi, T. (2012). Sequential memory scanning during Sternberg memory task regardless of the different presentation style. In *2012 ICME International Conference on Complex Medical Engineering (CME)* (pp. 86–89). IEEE. http://doi.org/10.1109/ICCME.2012.6275651

Olatunji, B. O., Armstrong, T., & Ciesielski, B. G. (2015). Differential effects of emotional expressions and scenes on visual search. *Motivation and Emotion*, *39*(4), 589–601. http://doi.org/10.1007/s11031-015-9477-y

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. http://doi.org/10.1016/0028-3932(71)90067-4

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology*, *77*(3), 247–265. http://doi.org/10.1016/j.biopsycho.2007.11.006

Orgo, L., Bachmann, M., Lass, J., & Hinrikus, H. (2015). Effect of negative and positive emotions on EEG spectral asymmetry. In *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (pp. 8107–8110). IEEE. http://doi.org/10.1109/EMBC.2015.7320275

Ortony, A., & Turner, T. J. (1990). What's Basic About Basic Emotions? *Psychological Review*, *97*(3), 315–331. http://doi.org/10.1037/0033-295X.97.3.315

Otto, B., Misra, S., Prasad, A., & McRae, K. (2014). Functional overlap of top-down emotion regulation and generation: an fMRI study identifying common neural substrates between cognitive reappraisal and cognitively generated emotions. *Cognitive, Affective & Behavioral Neuroscience*, *14*(3), 923–38. http://doi.org/10.3758/s13415-013-0240-0

Ovaysikia, S., Tahir, K. A., Chan, J. L., & DeSouza, J. F. X. (2011). Word Wins Over Face: Emotional Stroop Effect Activates the Frontal Cortical Network. *Frontiers in Human Neuroscience*, *4*. http://doi.org/10.3389/fnhum.2010.00234

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology/Revue Canadienne de Psychologie*, *45*(3), 255–287. http://doi.org/10.1037/h0084295

Paivio, A., & Csapo, K. (1971). Short-term sequential memory for pictures and words. *Psychonomic Science*, *24*(2), 50–51. http://doi.org/10.3758/BF03337887

Paivio, A., & Csapo, K. (1973). Picture superiority in free recall: Imagery or dual coding? *Cognitive Psychology*, *5*(2), 176–206. http://doi.org/10.1016/0010-0285(73)90032-7

Palumbo, L., Ogden, R., Makin, A. D. J., & Bertamini, M. (2014). Examining visual complexity and its influence on perceived duration. *Journal of Vision*, *14*(14), 3–3. http://doi.org/10.1167/14.14.3

Papez, J. W. (1937). A proposed mechanism of emotion. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *7*(1),

103–112. http://doi.org/7711480

Park, D. C., Puglisi, J. T., & Sovacool, M. (1983). Memory for pictures, words, and spatial location in older adults: evidence for pictorial superiority. *Journal of Gerontology*, *38*(5), 582–8. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6886314

Payne, L., & Kounios, J. (2009). Coherent oscillatory networks supporting short-term memory retention. *Brain Research*, *1247*, 126–132. http://doi.org/10.1016/j.brainres.2008.09.095

Pereira, M. G., Volchan, E., Machado-Pinheiro, W., Rodriguez, J. A., Nepomuceno, F. V. P., & Pessoa, L. (2004). Behavior modulation by mutilation pictures in women. *Brazilian Journal of Medical and Biological Research*, *37*(3), 353–362. http://doi.org/10.1590/S0100-879X2004000300011

Pessoa, L. (2005). To what extent are emotional visual stimuli processed without attention and awareness? *Current Opinion in Neurobiology*, *15*(2), 188–196. http://doi.org/10.1016/j.conb.2005.03.002

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews Neuroscience*, *9*(2), 148–58. http://doi.org/10.1038/nrn2317

Pessoa, L. (2013). *The Cognitive-Emotional Brain*. http://doi.org/10.7551/mitpress/9780262019569.001.0001

Pessoa, L. (2017). A Network Model of the Emotional Brain. *Trends in Cognitive Sciences*, *21*(5), 357–371. http://doi.org/10.1016/j.tics.2017.03.002

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.

http://doi.org/10.1073/pnas.172403899

Peterson, C. K., Gable, P., & Harmon-Jones, E. (2008). Asymmetrical frontal ERPs, emotion, and behavioral approach/inhibition sensitivity. *Social Neuroscience*, *3*(2), 113–124. http://doi.org/10.1080/17470910701612736

Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. *Neuron*. http://doi.org/10.1016/j.neuron.2005.09.025

Pinel, P., Dehaene, S., Rivière, D., & LeBihan, D. (2001). Modulation of Parietal Activation by Semantic Distance in a Number Comparison Task. *NeuroImage*, *14*(5), 1013–1026. http://doi.org/10.1006/nimg.2001.0913

Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: an integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and Psychopathology*, *17*(3), 715–34. http://doi.org/10.1017/S0954579405050340

Pourtois, G. (2004). Electrophysiological Correlates of Rapid Spatial Orienting Towards Fearful Faces. *Cerebral Cortex*, *14*(6), 619–633. http://doi.org/10.1093/cercor/bhh023

Pratto, F., & John, O. P. (1991). Automatic vigilance: the attention-grabbing power of negative social information. *Journal of Personality and Social Psychology*, *61*(3), 380–91. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1941510

Pulvermüller, F. (2013). How neurons make meaning: Brain mechanisms for embodied and abstract-symbolic semantics. *Trends in Cognitive Sciences*, *17*(9), 458–470. http://doi.org/10.1016/j.tics.2013.06.004

Pulvermüller, F., Moseley, R. L., Egorova, N., Shebani, Z., & Boulenger, V. (2014). Motor cognition-motor semantics: Action perception theory of cognition and communication. *Neuropsychologia*, *55*(1), 71–84. http://doi.org/10.1016/j.neuropsychologia.2013.12.002

Raghavachari, S., Kahana, M. J., Rizzuto, D. S., Caplan, J. B., Kirschen, M. P., Bourgeois, B., … Lisman, J. E. (2001). Gating of human theta oscillations by a working memory task. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *21*(9), 3175–83. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11312302

Reber, R., Perrig, W. J., Flammer, A., & Walter, D. (1994). Levels of processing and memory for emotional words. *Swiss Journal of Psychology / Schweizerische Zeitschrift Für Psychologie / Revue Suisse de Psychologie*. Switzerland: Verlag Hans Huber.

Rilling, J. K., King-Casas, B., & Sanfey, A. G. (2008). The neurobiology of social decision-making. *Current Opinion in Neurobiology*, *18*(2), 159–65. http://doi.org/10.1016/j.conb.2008.06.003

Ritchey, M., LaBar, K. S., & Cabeza, R. (2011). Level of Processing Modulates the Neural Correlates of Emotional Memory Formation. *Journal of Cognitive Neuroscience*, *23*(4), 757–771. http://doi.org/10.1162/jocn.2010.21487

Robinson, M. D., Storbeck, J., Meier, B. P., & Kirkeby, B. S. (2004). Watch out! That could be dangerous: valence-arousal interactions in evaluative processing. *Personality & Social Psychology Bulletin*, *30*(11), 1472–84. http://doi.org/10.1177/0146167204266647

Rolls, E. T. (2015). Limbic systems for emotion and for memory, but no single limbic system. *Cortex*, *62*, 119–157.

http://doi.org/10.1016/j.cortex.2013.12.005

Rosen, S., & Grandison, R. J. (1994). Effects of topic valence and pictorial distractor valence on verbalizing and evaluating topic-evoked visual imagery. *Motivation and Emotion*, *18*(3), 249–268. http://doi.org/10.1007/BF02254831

Rosinski, R. R., Golinkoff, R. M., & Kukish, K. S. (1975). Automatic Semantic Processing in a Picture-Word Interference Task. *Source: Child Development*, *46*(1), 247–253. http://doi.org/10.2307/1128859

Rossion, B., & Pourtois, G. (2004). Revisiting Snodgrass and Vanderwart's Object Pictorial Set: The Role of Surface Detail in Basic-Level Object Recognition. *Perception*, *33*(2), 217–236. http://doi.org/10.1068/p5117

Rowe, G., Hirsh, J. B., & Anderson, A. K. (2007). Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(1), 383–8. http://doi.org/10.1073/pnas.0605198104

Rudebeck, P. H., Bannerman, D. M., & Rushworth, M. F. S. (2008). The contribution of distinct subregions of the ventromedial frontal cortex to emotion, social behavior, and decision making. *Cognitive, Affective & Behavioral Neuroscience*, *8*(4), 485–97. http://doi.org/10.3758/CABN.8.4.485

Russell, J. a. (1978). Evidence of convergent validity on the dimensions of affect. *Journal of Personality and Social Psychology*, *36*(10), 1152–1168. http://doi.org/10.1037/0022-3514.36.10.1152

Russell, J. a. (1979). Affective space is bipolar. *Journal of Personality and Social Psychology*, *37*(3), 345–356.

http://doi.org/10.1037/0022-3514.37.3.345

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*(6), 1161–1178. http://doi.org/10.1037/h0077714

Sackeim, H. A., Gur, R. C., & Saucy, M. C. (1978). Emotions are expressed more intensely on the left side of the face. *Science (New York, N.Y.)*, *202*(4366), 434–6. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/705335

Sakaki, M., Gorlick, M. A., & Mather, M. (2011). Differential interference effects of negative emotional states on subsequent semantic and perceptual processing. *Emotion*, *11*(6), 1263–1278. http://doi.org/10.1037/a0026329

Sakaki, M., Niki, K., & Mather, M. (2012). Beyond arousal and valence: The importance of the biological versus social relevance of emotional stimuli. *Cognitive, Affective, & Behavioral Neuroscience*, *12*(1), 115–139. http://doi.org/10.3758/s13415-011-0062-x

Sanfey, A. G. (2003). The Neural Basis of Economic Decision-Making in the Ultimatum Game. *Science*, *300*(5626), 1755–1758. http://doi.org/10.1126/science.1082976

Santesso, D. L., Meuret, A. E., Hofmann, S. G., Mueller, E. M., Ratner, K. G., Roesch, E. B., & Pizzagalli, D. A. (2008). Electrophysiological correlates of spatial orienting towards angry faces: A source localization study. *Neuropsychologia*, *46*(5), 1338–1348. http://doi.org/10.1016/j.neuropsychologia.2007.12.013

Satpute, A. B., Hanington, L., & Barrett, L. F. (2016). Novel response patterns during repeated presentation of affective and neutral stimuli. *Social Cognitive and Affective Neuroscience*,

11(12), 1919–1932. http://doi.org/10.1093/scan/nsw104

Savine, A. C., Beck, S. M., Edwards, B. G., Chiew, K. S., & Braver, T. S. (2010). Enhancement of cognitive control by approach and avoidance motivational states. *Cognition & Emotion*, *24*(2), 338–356. http://doi.org/10.1080/02699930903381564

Schack, B., Vath, N., Petsche, H., Geissler, H.-G., & Möller, E. (2002). Phase-coupling of theta-gamma EEG rhythms during short-term memory processing. *International Journal of Psychophysiology : Official Journal of the International Organization of Psychophysiology*, *44*(2), 143–63. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11909647

Schaefer, A., & Philippot, P. (2005). Selective effects of emotion on the phenomenal characteristics of autobiographical memories. *Memory*, *13*(2), 148–160. http://doi.org/10.1080/09658210344000648

Schendan, H. E., Ganis, G., & Kutas, M. (1998). Neurophysiological evidence for visual perceptual categorization of words and faces within 150 ms. *Psychophysiology*, *35*(3), 240–51. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9564744

Schlochtermeier, L. H., Kuchinke, L., Pehrs, C., Urton, K., Kappelhoff, H., & Jacobs, A. M. (2013). Emotional Picture and Word Processing: An fMRI Study on Effects of Stimulus Complexity. *PLoS ONE*, *8*(2), e55619. http://doi.org/10.1371/journal.pone.0055619

Schlosberg, H. (1954). Three Dimensions of Emotion. *The Psychological Review*, *61*(2), 81–88. http://doi.org/10.1126/science.3.71.712-a

Schmidt, L. A., & Trainor, L. J. (2001). Frontal brain electrical activity (EEG) distinguishes valence and intensity of musical

emotions. *Cognition and Emotion*, *15*(4), 487–500. http://doi.org/10.1080/0269993004200187

Schmithorst, V. J., & Brown, R. D. (2004). Empirical validation of the triple-code model of numerical processing for complex math operations using functional MRI and group Independent Component Analysis of the mental addition and subtraction of fractions. *NeuroImage*, *22*(3), 1414–1420. http://doi.org/10.1016/j.neuroimage.2004.03.021

Schmitz, T. W., De Rosa, E., & Anderson, A. K. (2009). Opposing influences of affective state valence on visual cortical encoding. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *29*(22), 7199–207. http://doi.org/10.1523/JNEUROSCI.5387-08.2009

Schneider, M., Chau, L., Mohamadpour, M., Stephens, N., Arya, K., & Grant, A. (2016). EEG asymmetry and BIS/BAS among healthy adolescents. *Biological Psychology*, *120*, 142–148. http://doi.org/10.1016/j.biopsycho.2016.09.004

Schönwald, L. I., & Müller, M. M. (2014). Slow biasing of processing resources in early visual cortex is preceded by emotional cue extraction in emotion-attention competition. *Human Brain Mapping*, *35*(4), 1477–1490. http://doi.org/10.1002/hbm.22267

Schulte Holthausen, B., Regenbogen, C., Turetsky, B. I., Schneider, F., & Habel, U. (2016). The Influence of Task-Irrelevant Flankers Depends on the Composition of Emotion Categories. *Frontiers in Psychology*, *7*(JUL), 1–9. http://doi.org/10.3389/fpsyg.2016.00712

Schwager, S., & Rothermund, K. (2013). Counter-regulation triggered by emotions: Positive/negative affective states elicit opposite valence biases in affective processing. *Cognition &*

Emotion, *27*(5), 839–855. http://doi.org/10.1080/02699931.2012.750599

Seifert, L. S. (1997). Activating representations in permanent memory: different benefits for pictures and words. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *23*(5), 1106–21. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9293624

Sergerie, K., Chochol, C., & Armony, J. L. (2008). The role of the amygdala in emotional processing: A quantitative meta-analysis of functional neuroimaging studies. *Neuroscience & Biobehavioral Reviews*, *32*(4), 811–830. http://doi.org/10.1016/j.neubiorev.2007.12.002

Shafer, A., Iordan, A., Cabeza, R., & Dolcos, F. (2011). Brain Imaging Investigation of the Memory-Enhancing Effect of Emotion. *Journal of Visualized Experiments*, (51), 1–5. http://doi.org/10.3791/2433

Shafer, A. T., Matveychuk, D., Penney, T., O'Hare, A. J., Stokes, J., & Dolcos, F. (2012). Processing of Emotional Distraction Is Both Automatic and Modulated by Attention: Evidence from an Event-related fMRI Investigation. *Journal of Cognitive Neuroscience*, *24*(5), 1233–1252. http://doi.org/10.1162/jocn_a_00206

Shah, A., Jhawar, S. S., & Goel, A. (2012). Analysis of the anatomy of the Papez circuit and adjoining limbic system by fiber dissection techniques. *Journal of Clinical Neuroscience*, *19*(2), 289–298. http://doi.org/10.1016/j.jocn.2011.04.039

Shepard, R. N. (1967). Recognition memory for words, sentences, and pictures. *Journal of Verbal Learning and Verbal Behavior*, *6*(1), 156–163. http://doi.org/10.1016/S0022-5371(67)80067-7

Sianipar, A., van Groenestijn, P., & Dijkstra, T. (2016). Affective Meaning, Concreteness, and Subjective Frequency Norms for Indonesian Words. *Frontiers in Psychology*, *7*. http://doi.org/10.3389/fpsyg.2016.01907

Smith, S. D., & Bulman-Fleming, M. B. (2004). A hemispheric asymmetry for the unconscious perception of emotion. *Brain and Cognition*, *55*(3), 452–457. http://doi.org/10.1016/j.bandc.2004.02.064

Smith, S. D., & Bulman-Fleming, M. B. (2005). An examination of the right-hemisphere hypothesis of the lateralization of emotion. *Brain and Cognition*, *57*(2), 210–213. http://doi.org/10.1016/j.bandc.2004.08.046

Smith, B. D., Meyers, M., Kline, R., & Bozman, A. (1987). Hemispheric asymmetry and emotion: Lateralized parietal processing of affect and cognition. *Biological Psychology, 25(3)*, 247–260. http://doi.org/10.1016/0301-0511(87)90050-0

Snider, R. S., & Maiti, A. (1976). Cerebellar contributions to the Papez circuit. *Journal of Neuroscience Research*, *2*(2), 133–146. http://doi.org/10.1002/jnr.490020204

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning & Memory*, *6*(2), 174–215. http://doi.org/10.1037/0278-7393.6.2.174

Spielberger, C. D., Gorsuch, R. L., Lushene, P. R., Vagg, P. R., & Jacobs, A. G. (1983). *Manual for the State-Trait Anxiety Inventory (Form Y)*. *Manual for the statetrait anxiety inventory STAI*. http://doi.org/10.1007/978-1-4419-9893-4

Sprengelmeyer, R., Rausch, M., Eysel, U. T., & Przuntek, H.

(1998). Neural structures associated with recognition of facial expressions of basic emotions. *Proceedings of the Royal Society B: Biological Sciences*, *265*(1409), 1927–1931. http://doi.org/10.1098/rspb.1998.0522

Stadthagen-Gonzalez, H., & Davis, C. J. (2006). The Bristol norms for age of acquisition, imageability, and familiarity. *Behavior Research Methods*, *38*(4), 598–605. http://doi.org/10.3758/BF03193891

Sternberg, S. (1969). Memory-scanning: mental processes revealed by reaction-time experiments. *American Scientist*. http://doi.org/10.1037/10814-012

Storbeck, J., & Clore, G. L. (2007). On the interdependence of cognition and emotion. *Cognition & Emotion*, *21*(6), 1212–1237. http://doi.org/10.1080/02699930701438020

Storbeck, J., & Clore, G. L. (2008). The affective regulation of cognitive priming. *Emotion (Washington, D.C.)*, *8*(2), 208–15. http://doi.org/10.1037/1528-3542.8.2.208

Strata, P., Scelfo, B., & Sacchetti, B. (2011). Involvement of cerebellum in emotional behavior. *Physiological Research*, *60*(SUPPL.1).

Straube, T., Pohlack, S., Mentzel, H. J., & Miltner, W. H. R. (2008). Differential amygdala activation to negative and positive emotional pictures during an indirect task. *Behavioural Brain Research*, *191*(2), 285–288. http://doi.org/10.1016/j.bbr.2008.03.040

Stroop, J. R. (1935). Stroop color word test. *J. Exp. Physiol.*, (18), 643–662. http://doi.org/10.1007/978-0-387-79948-3

Sussman, T. J., Heller, W., Miller, G. A., & Mohanty, A. (2013). Emotional Distractors Can Enhance Attention. *Psychological*

Science, *24*(11), 2322–2328. http://doi.org/10.1177/0956797613492774

Szily, E., & Keri, S. (2008). Emotion-related brain regions. *Ideggyogyaszati Szemle*, *61*(3–4), 77–86. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med5&NEWS=N&AN=18459448

Tandle, A., Jog, N., Dharmadhikari, A., & Jaiswal, S. (2016). Estimation of valence of emotion from musically stimulated EEG using frontal theta asymmetry. In *2016 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD)* (pp. 63–68). IEEE. http://doi.org/10.1109/FSKD.2016.7603152

THAYER, R. E. (1967). MEASUREMENT OF ACTIVATION THROUGH SELF-REPORT Monograph Supplement 1-V20. *Psychological Reports*, *20*(2), 663–678. http://doi.org/10.2466/pr0.1967.20.2.663

Thomas, R. C., & Hasher, L. (2006). The influence of emotional valence on age differences in early processing and memory. *Psychology and Aging*, *21*(4), 821–825. http://doi.org/10.1037/0882-7974.21.4.821

Torrubia, R., Ávila, C., Moltó, J., & Caseras, X. (2001). The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences*, *31*(6), 837–862. http://doi.org/10.1016/S0191-8869(00)00183-5

Trauer, S. M., Andersen, S. K., Kotz, S. A., & Müller, M. M. (2012). Capture of lexical but not visual resources by task-irrelevant emotional words: A combined ERP and steady-state visual evoked potential study. *NeuroImage*, *60*(1), 130–138.

http://doi.org/10.1016/j.neuroimage.2011.12.016

Tuladhar, A. M., Huurne, N., Schoffelen, J.-M., Maris, E., Oostenveld, R., & Jensen, O. (2007). Parieto-occipital sources account for the increase in alpha activity with working memory load. *Human Brain Mapping*, *28*(8), 785–792. http://doi.org/10.1002/hbm.20306

Turner, T. J., & Ortony, A. (1992). Basic emotions: can conflicting criteria converge? *Psychological Review*, *99*(3), 566–71. http://doi.org/10.1037/0033-295X.99.3.566

Valenza, G., Greco, A., Lanata, A., Gentili, C., Menicucci, D., Sebastiani, L., … Scilingo, E. P. (2015). Brain dynamics during emotion elicitation in healthy subjects: An EEG study. In *2015 AEIT International Annual Conference (AEIT)* (pp. 1–3). IEEE. http://doi.org/10.1109/AEIT.2015.7415274

Van Honk, J., & Schutter, D. J. L. G. (2006). From affective valence to motivational direction: The frontal asymmetry of emotion revised. *Psychological Science*, *17*(11), 963–965. http://doi.org/10.1111/j.1467-9280.2006.01813.x

van Hooff, J. C., Dietz, K. C., Sharma, D., & Bowman, H. (2008). Neural correlates of intrusion of emotion words in a modified Stroop task. *International Journal of Psychophysiology : Official Journal of the International Organization of Psychophysiology*, *67*(1), 23–34. http://doi.org/10.1016/j.ijpsycho.2007.09.002

van Vugt, M. K., Schulze-Bonhage, A., Litt, B., Brandt, A., & Kahana, M. J. (2010). Hippocampal gamma oscillations increase with memory load. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *30*(7), 2694–9. http://doi.org/10.1523/JNEUROSCI.0567-09.2010

Vandenberghe, R., Price, C., Wise, R., Josephs, O., & Frackowiak,

R. S. (1996). Functional anatomy of a common semantic system for words and pictures. *Nature*, *383*(6597), 254–6. http://doi.org/10.1038/383254a0

Veltman, D. J., Rombouts, S. A. R. B., & Dolan, R. J. (2003). Maintenance versus manipulation in verbal working memory revisited: an fMRI study. *NeuroImage*, *18*(2), 247–56. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12595179

Vervoort, L., Wolters, L. H., Hogendoorn, S. M., de Haan, E., Boer, F., & Prins, P. J. M. (2010). Sensitivity of Gray's Behavioral Inhibition System in clinically anxious and non-anxious children and adolescents. *Personality and Individual Differences*, *48*(5), 629–633. http://doi.org/10.1016/j.paid.2009.12.021

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 (Washington, D.C.)*, *8*(6), 880–5. http://doi.org/10.1037/a0013981

Vromen, J. M. G., Lipp, O. V., Remington, R. W., & Becker, S. I. (2016). Threat captures attention, but not automatically: Top-down goals modulate attentional orienting to threat distractors. *Attention, Perception, & Psychophysics*, *78*(7), 2266–2279. http://doi.org/10.3758/s13414-016-1142-3

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in Cognitive Sciences*, *9*(12), 585–94. http://doi.org/10.1016/j.tics.2005.10.011

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. http://doi.org/10.1016/S0896-6273(01)00328-2

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 B: Biological Sciences*, *362*(1481), 837–855. http://doi.org/10.1098/rstb.2007.2092

Wager, T. D., Phan, K. L., Liberzon, I., & Taylor, S. F. (2003). Valence, gender, and lateralization of functional brain anatomy in emotion: a meta-analysis of findings from neuroimaging. *NeuroImage*, *19*(3), 513–31. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12880784

Warriner, A. B., Kuperman, V., & Brysbaert, M. (2013). Norms of valence, arousal, and dominance for 13,915 English lemmas. *Behavior Research Methods*, *45*(4), 1191–207. http://doi.org/10.3758/s13428-012-0314-x

Weinberg, A., & Hajcak, G. (2011). The Late Positive Potential Predicts Subsequent Interference with Target Processing. *Journal of Cognitive Neuroscience*, *23*(10), 2994–3007. http://doi.org/10.1162/jocn.2011.21630

Weinreich, A., Stephani, T., & Schubert, T. (2016). Emotion effects within frontal alpha oscillation in a picture oddball paradigm. *International Journal of Psychophysiology*, *110*, 200–206. http://doi.org/10.1016/j.ijpsycho.2016.07.517

Wesslein, A.-K., Spence, C., & Frings, C. (2014). Vision affects tactile target and distractor processing even when space is task-irrelevant. *Frontiers in Psychology*, *5*, 84. http://doi.org/10.3389/fpsyg.2014.00084

Wiens, S., & Syrjänen, E. (2013). Directed attention reduces processing of emotional distracters irrespective of valence and arousal level. *Biological Psychology*, *94*(1), 44–54. http://doi.org/10.1016/j.biopsycho.2013.05.001

Wisco, B. E., Treat, T. A., & Hollingworth, A. (2012). Visual attention to emotion in depression: Facilitation and withdrawal processes. *Cognition & Emotion*, *26*(4), 602–614. http://doi.org/10.1080/02699931.2011.595392

Wiswede, D., Münte, T. F., Goschke, T., & Rüsseler, J. (2009). Modulation of the error-related negativity by induction of short-term negative affect. *Neuropsychologia*, *47*(1), 83–90. http://doi.org/10.1016/j.neuropsychologia.2008.08.016

Wright, C. I., Fischer, H., Whalen, P. J., McInerney, S. C., Shin, L. M., & Rauch, S. L. (2001). Differential prefrontal cortex and amygdala habituation to repeatedly presented emotional stimuli. *Neuroreport*, *12*(2), 379–83. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11209954

Xie, X., Mulej Bratec, S., Schmid, G., Meng, C., Doll, A., Wohlschläger, A., … Sorg, C. (2016). How do you make me feel better? Social cognitive emotion regulation and the default mode network. *NeuroImage*, *134*, 270–280. http://doi.org/10.1016/j.neuroimage.2016.04.015

Yang, P., Wang, M., Jin, Z., & Li, L. (2015). Visual short-term memory load modulates the early attention and perception of task-irrelevant emotional faces. *Frontiers in Human Neuroscience*, *9*. http://doi.org/10.3389/fnhum.2015.00490

Zhang, Q., Liu, X., An, W., Yang, Y., & Wang, Y. (2015). Recognition memory of neutral words can be impaired by task-irrelevant emotional encoding contexts: behavioral and electrophysiological evidence. *Frontiers in Human Neuroscience*, *9*. http://doi.org/10.3389/fnhum.2015.00073

Appendix 1 – Stimuli used

Table 1 – IAPS database stimuli

Positive		
Picture Number	Valence Mean (SD)	Arousal Mean (SD)
1419	6.54(1.45)	3.48(1.95)
1603	6.90(1.48)	3.37(2.20)
1604	7.11(1.41)	3.30(2.17)
1605	6.59(1.56)	3.43(2.02)
1610	7.82(1.34)	3.08(2.19)
1620	7.37(1.56)	3.54(2.34)
1670	6.81(1.76)	3.05(1.91)
1812	6.83(1.33)	3.60(2.11)
1910	6.71(1.80)	3.29(2.29)
2035	7.52(1.33)	3.69(2.11)
2299	7.27(1.53)	3.95(2.22)
2304	7.22(1.31)	3.63(2.15)
2360	7.70(1.76)	3.66(2.32)
2370	7.14(1.46)	2.90(2.14)
2387	7.12(1.58)	3.97(2.18)
2388	7.44(1.44)	3.77(2.21)
2501	6.89(1.78)	3.09(2.21)
2598	7.19(1.30)	3.73(1.84)
5000	7.08(1.77)	2.67(1.99)
5001	7.16(1.56)	3.79(2.34)
5010	7.14(1.50)	3.00(2.25)
5200	6.96(1.62)	3.46(2.06)
5202	7.25(1.44)	3.73(2.22)

5220	7.01(1.50)	3.91(2.27)
5551	7.31(1.63)	3.26(2.47)
5631	7.29(1.34)	3.86(2.64)
5711	6.62(1.65)	3.03(1.96)
5725	7.09(1.41)	3.55(2.32)
5750	6.60(1.84)	3.14(2.25)
5760	8.05(1.23)	3.22(2.39)
5764	6.74(1.64)	3.55(2.32)
5779	7.33(1.42)	3.57(2.30)
5780	7.52(1.45)	3.75(2.54)
5781	7.13(1.49)	3.82(2.37)
5811	7.23(1.60)	3.30(2.33)
5870	6.78(1.76)	3.10(2.22)
5891	7.22(1.46)	3.29(2.57)
7325	7.06(1.65)	3.55(2.07)
7340	6.68(1.63)	3.69(2.58)
7545	6.84(1.72)	3.28(2.34)
Mean	7.10 (1.53)	3.45 (2.23)
Negative Picture Number	Valence Mean (SD)	Arousal Mean (SD)
2039	3.65(1.44)	3.46(1.94)
2206	4.06(1.40)	3.71(2.03)
2210	4.38(1.64)	3.08(1.76)
2221	4.39(1.21)	3.07(2.08)
2271	4.20(1.26)	3.74(1.69)
2280	4.22(1.54)	3.77(1.89)
2312	3.71(1.64)	4.02(1.66)
2399	3.69(1.40)	3.93(2.01)
2490	3.32(1.82)	3.95(2.00)
2491	4.14(1.29)	3.41(1.73)

2520	4.13(1.90)	4.22(1.69)
2525	4.06(1.93)	3.93(2.16)
2590	3.26(1.92)	3.93(1.94)
2722	3.47(1.65)	3.52(2.05)
5120	4.39(1.34)	3.07(2.12)
6010	3.73(1.98)	3.95(1.87)
7013	4.20(1.35)	4.11(2.02)
7023	3.80(1.71)	4.17(2.13)
7046	4.18(1.38)	4.14(2.04)
7054	4.14(1.09)	4.08(2.13)
7078	3.79(1.45)	3.69(1.86)
7234	4.23(1.58)	2.96(1.90)
7290	4.37(1.54)	3.87(2.07)
7700	4.25(1.45)	2.95(2.17)
8010	4.58(1.87)	4.12(2.13)
9000	2.55(1.55)	4.06(2.25)
9001	3.10(2.02)	3.67(2.30)
9010	3.94(1.70)	4.14(2.05)
9045	3.75(1.67)	3.89(2.16)
9090	3.69(1.92)	3.97(2.12)
9101	3.62(1.96)	4.02(2.33)
9110	3.76(1.41)	3.98(2.23)
9190	3.90(1.44)	3.91(1.73)
9220	2.06(1.54)	4.00(2.09)
9331	2.87(1.28)	3.85(2.00)
9360	4.03(1.38)	2.63(1.75)
9390	4.04(1.67)	3.54(2.41)
9395	3.23(1.31)	3.73(2.12)
9469	4.00(1.50)	4.08(1.85)
9472	4.07(1.34)	4.16(2.00)
Mean	3.82(1.56)	3.76(2.01)

Table 2 – NAPS database stimuli

Distractors - Negative			
Picture Number	Valence Mean (SD)	Arousal Mean (SD)	Complexity
Animals_017_v	3.28(1.43)	5.76(1.36)	High
Animals_031_h	4.58(1.34)	5.38(1.05)	High
Faces_155_h	3.98(1.32)	5.17(1.2)	Low
Faces_157_h	4.25(1.32)	4.61(1.55)	High
Faces_281_h	4.5(1.15)	5(1.58)	High
Landscapes_010_h	3.29(1.47)	5.33(1.6)	Low
Landscapes_012_h	4.4(0.94)	4.62(1.42)	High
Landscapes_013_v	4.35(1.62)	5.07(0.95)	High
Landscapes_032_v	4.29(1.04)	5.32(0.93)	High
Landscapes_078_h	4.5(1.22)	4.86(1.53)	High
Objects_010_h	4.5(1.47)	4.93(1.22)	High
Objects_116_v	4.02(0.97)	4.52(1.39)	Low
Objects_122_h	4.08(1.27)	5(1.32)	Low
Objects_128_h	4.04(1.2)	5.2(1.11)	Low
Objects_145_h	3.47(1.31)	5.16(1.97)	Low
Objects_164_h	4.25(1.28)	5.12(1.36)	Low
Objects_175_h	4.43(1.06)	5(0.96)	Low
Objects_215_v	4.08(0.94)	5.22(0.99)	Low
Objects_234_h	4.43(0.92)	4.97(0.79)	High
Objects_235_h	3.96(1.35)	5.27(1.18)	High
Objects_236_h	4.06(1.29)	5.09(1.14)	High
Objects_248_h	4.37(1.22)	5.15(0.73)	Low
People_080_h	4.02(2.28)	5.13(1.87)	Low
People_117_h	3.94(1.1)	5.32(1.2)	Low
Mean	4.13(1.26)	5.07(1.27)	
Distractors - Positive			
Picture Number	Valence Mean (SD)	Arousal Mean (SD)	Complexity
Animals_177_h	8.09(1.05)	4.37(2.75)	Low

Animals_183_h	7.65(1.47)	4.29(2.52)	High
Faces_081_v	7.6(1.47)	4.76(1.92)	High
Faces_109_v	8.17(1.02)	4.6(2.35)	Low
Faces_122_h	7.85(1.24)	5.1(2.17)	Low
Faces_134_h	7.43(1.22)	5.68(2.1)	High
Faces_140_h	7.63(1.3)	4.68(2.05)	Low
Faces_321_h	7.34(1.34)	6.21(1.64)	High
Faces_340_h	7.29(1.34)	4.97(2.34)	High
Landscapes_021_h	7.6(1.12)	3.73(2.59)	Low
Landscapes_098_h	7.87(1.2)	2.56(1.7)	Low
Landscapes_141_h	8.04(1.12)	2.2(1.49)	Low
Objects_037_h	7.23(1.34)	5.42(2.07)	High
Objects_327_h	7.67(1.32)	3.55(2.46)	High
People_043_h	7.64(1.31)	4.33(2.01)	Low
People_054_h	7.55(1.25)	3.2(1.61)	Low
People_068_h	7.11(1.22)	5.16(2)	Low
People_096_h	7.78(1.33)	5.4(2.76)	Low
People_172_v	8.02(1)	4.53(2.47)	High
People_185_h	7.63(1.28)	4.98(2.65)	High
People_187_h	7.84(1.2)	5.78(2.18)	High
People_189_h	7.06(1.57)	6.03(2.07)	High
People_193_h	7.3(1.3)	6(2.29)	High
People_196_h	7.58(1.25)	5.85(2.25)	Low
Mean	7.58(1.26)	4.72(2.18)	

Targets - Negative		
Picture Number	Valence Mean (SD)	Arousal Mean (SD)
Animals_086_v	4.45(1.77)	5.43(1.45)
Faces_169_v	4.47(1.61)	4.98(1.7)
Faces_204_v	4.23(1.34)	5.09(1.11)
Faces_278_h	4.46(1.28)	5.33(0.83)
Landscapes_006_h	3.92(1.32)	4.98(1.71)
Landscapes_027_v	4.43(1.09)	5.36(0.94)
Landscapes_028_h	3.83(1.8)	5.19(1.74)
Landscapes_074_h	4.04(1.27)	4.98(1.13)
Landscapes_156_h	4.19(1.21)	5.36(0.99)
Objects_127_h	3.66(1.17)	5.38(1.05)

Objects_134_h	4.32(0.88)	4.84(0.96)
Objects_135_h	3.92(0.99)	5.06(1.32)
Objects_140_h	3.79(1.38)	5.09(1.64)
Objects_146_h	4.48(1.07)	4.88(1.19)
Objects_156_v	4.06(1.19)	5.3(0.93)
Objects_159_v	4.17(1.23)	5.04(1.15)
Objects_173_h	3.76(1.19)	5.31(1)
Objects_184_v	4.18(1.26)	5.05(0.73)
Objects_207_h	3.78(1.21)	5.13(1.06)
Objects_242_h	4.09(1.28)	5.17(1.2)
Objects_252_h	4.41(1.07)	5.28(1.02)
Objects_282_h	4.36(1)	5.09(0.87)
People_083_h	3.56(1.5)	5.54(1.46)
People_141_h	4.15(1.41)	5.53(1.37)
Mean	4.11(1.27)	5.18(1.19)

Targets - Positive		
Picture Number	Valence Mean (SD)	Arousal Mean (SD)
Animals_172_h	7.71(1.17)	4.71(2.35)
Animals_179_h	7.51(1.52)	5.38(2.36)
Faces_001_h	7.76(1.15)	4.24(2.61)
Faces_361_v	7.09(1.1)	5.82(1.57)
Faces_107_h	7.53(1.1)	4.91(2.04)
Faces_120_h	7.67(1.72)	5.17(1.58)
Faces_127_h	7.59(1.19)	4.92(2.12)
Faces_136_v	7.46(1.16)	5.2(1.96)
Faces_232_h	7.26(1.38)	4.98(1.75)
Faces_342_h	7.13(1.3)	5.45(2.14)
Faces_347_h	7(1.3)	5.74(1.7)
Faces_352_h	7.17(1.3)	5.61(1.96)
Faces_356_h	7.65(1.22)	5.34(2.16)
Landscapes_008_h	7.4(1.41)	4.41(2.84)
Landscapes_178_h	7.69(1.31)	4.02(2.48)
Objects_171_h	7.06(1.45)	5.39(2.25)
Landscapes_161_h	7.58(1.46)	4.08(2.31)
Objects_074_v	7.55(1.38)	4.85(2.39)
Objects_076_v	7.25(1.44)	4.89(2.06)

Objects_080_h	7.55(1.27)	5.2(2.24)
People_160_h	7.4(1.36)	5.25(2.65)
Objects_077_h	7.71(1.18)	4.35(1.97)
People_174_v	7.52(1.28)	4.9(2.43)
People_180_h	7.06(1.17)	5.52(2.31)
Mean	7.43(1.26)	5.01(2.18)

Table 3 – Warriner database stimuli

Distractors - Negative			
Word	Valence Mean (SD)	Arousal Mean (SD)	Familiarity
abandon	2.84(1.54)	3.73(2.43)	Low
accuse	2.68(1.63)	5.32(2.08)	High
annoy	2.49(1.42)	5.04(2.4)	High
argue	3.15(1.53)	6.67(2.61)	High
decay	2.4(1.57)	4.59(2.59)	Low
deceive	2.95(1.43)	5.9(2.17)	Low
demolish	2.67(1.74)	4.5(1.82)	High
destroy	2.67(2.3)	5.16(2.85)	High
divorce	2.49(1.96)	5.39(2.62)	High
dread	3(1.89)	4.5(2.4)	Low
enslave	2.67(2.13)	5.35(2.28)	Low
evict	2.63(1.95)	4.73(2.75)	Low
forbid	2.82(1.33)	4.85(2.57)	High
grieve	2.8(1.79)	4.56(2.48)	High
imprison	2.48(1.72)	4.7(2.49)	Low
infect	2.84(1.68)	4(2.02)	Low
loathe	2.68(1.92)	5.18(2.26)	Low
neglect	2.16(1.21)	4.72(2.49)	Low
panic	2.56(1.55)	6.4(2.26)	High
paralyze	2.52(1.78)	4.47(2.37)	High

snarl	2.45(1.26)	5.85(2.2)	Low
threaten	2.6(1.57)	6.05(2.36)	High
violate	2.61(1.5)	5.76(2.77)	Low
waste	2.61(1.38)	4.04(2.27)	High
Mean	2.66(1.67)	5.11(2.4)	
Distractors - Positive			
Word	Valence Mean (SD)	Arousal Mean (SD)	Familiarity
achieve	7.75(1.16)	4.7(2.96)	High
admire	7.35(1.27)	5(2.27)	High
adore	7.37(1.38)	5.96(2.33)	Low
amaze	7.24(2)	5(2.25)	Low
amuse	7.1(1.37)	5.17(1.99)	Low
bake	7.2(1.61)	5(2.87)	High
brighten	7.37(1.42)	5.32(2.64)	Low
care	7.64(1.29)	2.67(1.85)	High
cuddle	7.6(0.99)	3.83(2.96)	High
date	7.18(1.5)	4.33(2.5)	High
entertain	7.21(1.81)	5.19(2.86)	Low
flourish	7.21(1.58)	5.22(2.33)	Low
forgive	7.06(2.1)	3.62(3.11)	High
heal	7.41(1.73)	4.32(2.54)	High
inspire	7.42(1.71)	5.9(2.64)	Low
receive	7.14(1.67)	4.3(2.75)	High
rejoice	7.14(1.98)	5.56(2.57)	Low
relax	7.82(2.04)	2.38(2.13)	High
relieve	7.25(1.59)	3.9(2.31)	Low
shine	7.27(1.39)	5.19(2.4)	Low
surprise	7.44(1.58)	6.57(2.75)	High
thank	7.77(1.41)	3.33(2.31)	High
treasure	7.65(0.93)	6.3(2.68)	Low

triumph	7.34(1.76)	5.6(2.63)	Low
Mean	7.37(1.55)	4.76(2.53)	
Targets - Negative			
Word	Valence Mean (SD)	Arousal Mean (SD)	
betray	2.52(1.92)	5.33(2.51)	
blame	2.94(1.92)	4.81(2.84)	
bleed	2.47(1.43)	5(2.31)	
cheat	3.05(1.9)	4.91(2.71)	
curse	2.9(2.17)	5.2(2.38)	
fail	2.33(1.32)	5.5(2.76)	
fear	2.93(1.79)	6.14(2.76)	
harass	2.95(1.47)	6.1(2.45)	
harm	1.91(1.11)	5.9(2.29)	
hate	1.96(1.33)	6.26(2.31)	
hurt	2.45(1.47)	4.72(2.34)	
kidnap	2.19(1.29)	5.59(2.75)	
mourn	2.4(1.73)	4.95(2.93)	
perish	2.22(1.22)	5.19(2.34)	
reject	2.95(1.75)	4.78(2.02)	
ruin	2.32(1.36)	5.4(2.52)	
slay	2.63(1.54)	4.9(2.28)	
smother	2.68(1.57)	4.75(2.59)	
starve	2.53(1.02)	4(2.59)	
stink	2.35(1.27)	4.48(2.27)	
sue	2.18(1.22)	6.15(2.46)	
suffer	2.05(1.32)	4.5(2.34)	
terrify	2.84(1.74)	6.39(2.55)	
worry	2.1(1.26)	6.33(2.73)	
Mean	2.49(1.5)	5.3(2.5)	

Targets - Positive		
Word	Valence Mean (SD)	Arousal Mean (SD)
cheer	7.1(1.5)	5.33(2.47)
dance	7.27(1.49)	5.48(2.62)
desire	7.05(1.75)	6.2(2.33)
dream	7.43(1.8)	4.37(2.81)
earn	7(1.2)	4.35(3.12)
enjoy	7.67(1.33)	5(3.03)
excite	7.79(1.36)	6.61(2.43)
help	6.95(2.01)	4.29(2.43)
hug	8.23(0.87)	4.85(2.95)
joke	7.88(1.44)	5.73(2.37)
kiss	7.78(1.64)	6.05(3.03)
laugh	7.56(2.64)	6.62(1.91)
like	7.44(1.46)	4.4(2.5)
live	7.95(1.17)	4.71(2.57)
love	8(1.39)	5.36(3.23)
marry	7.09(2.2)	5.52(2.96)
party	7.18(1.97)	6.08(2.8)
play	7.55(1.34)	3.81(2.56)
save	7.26(1.59)	4.62(2.46)
sing	7.5(1.37)	4.1(2.49)
smile	7.89(2.19)	4.62(3.09)
trust	7.24(1.96)	4.3(2.7)
win	6.97(2.09)	5.61(3.24)
wish	7.14(1.77)	3.38(2.33)
Mean	7.45(1.64)	5.05(2.68)

Appendix 2 – Pilot studies run before each experiment.

The following section describes, for each of the five experiments portrayed in the thesis, the elements tested in the different pilot studies and the procedure to determine the best setup for each experiment. Quantitative measures are not reported, since most of the data, particularly at the earlier stages of testing, were discarded.

Study 1.

We initially tested the magnitude of the numbers to be presented. After two different pilots, we decided to present only single-digit numbers. After a third pilot, we decided to remove the digits 1 and 9 since they drove significantly faster responses than all the other digits when used as first number to compare (i.e. the participants already prepared the response without waiting for the second number to appear and complete the magnitude comparison task).

The size of the numbers and the size of the distractors presented were tested through a series of three studies. We progressively reduced the size and adapted the number/picture size ratio to a level judged comfortable by the participants. In the final version of the study, size of the numbers resulted optimal, the pictures were judged as comfortably visible even in some details (compatibly with the timing of presentation on screen) and the flow between the elements of each trial (first number – distractor – second number) was judged smooth and not effortful in any component. For example, the presentation of the numbers in a font judged too big was creating visual adaptation problems due to the brightness of the digit (white on grey background, as illustrated in Fig. 7) compared to the subsequent picture. Moreover, digits too big in

font size were judged harder to stare at and the full experimental session was judged more effortful.

We then tested three response devices for the study. Two were response boxes (Cedrus RB-830 and Cedrus RB-730) and one was a standard Apple keyboard. From the manufacturer's information sheet, and considering the configuration of the computers used and the ports that connected each device to the pc, we estimated a higher delay for the Apple keyboard compared to the response boxes in the order of 10ms. This was due to hardware communication specifications. For this reason, we discarded the keyboard for the current study and tested, in a pilot study, the difference between the two response boxes. Since the performance was similar in terms of lags and experimental needs, we let the participants provide a feedback on each device. We picked the RB-830 model as it was judged more comfortable for the positioning of the fingers on the keys and the shape of the keyboard.

The creation of the scrambled stimuli required a series of tests to maintain the visual properties constant but make the affective content not discernible. We implemented a staircase process using the Gimp software (version 2.8) to obtain the desired effect and repeated the procedure for each picture. The image was divided in a series of rectangles after specifying the number of rows and columns wanted (for example, a combination of 3 columns and 2 rows gave origin to 6 tiles). Each tile was then moved, on the x- and y-axes, of N places (to the top or to the bottom, to the left or to the right), with N ranging between 0 and a maximum value M. The process was then iterated for a certain number of times. In this case, we piloted three parameters, specifically, the number of rows/columns created, the maximum number of positions for each tile to move and the number of iterations. The process was a

staircase one, for each parameter, until the ideal values were determined. In the final version, we used 20 divisions on the bigger dimension (20 rows on portrait pictures, 20 columns on landscape pictures) and 10 divisions on the smaller dimension (10 columns on portrait pictures, 10 rows on landscape pictures). The maximum number of positions moved was 8 and the number of iterations was included between 6 and 9, depending on the picture.

We also tested the length of each experimental window through a staircase process. We increased the duration of the number windows from 300 to 1000ms, with increases of 50ms, and the duration of the distractor window between 500 and 2000ms, with increases of 100ms. For each test, either one or both values were changed, until the best combination of durations was found. Four different combinations were proposed to a pool of 4 to 6 participants, to define the best presentation timing.

Finally, we ran the protocol on one participant to test the EEG capabilities and the full presentation of the behavioural test. Once the EEG capabilities were tested, we run a final pilot test on three participants to control for both neural and behavioural markers relevant for the experiment. The results of this pilot study have been presented, in the form of a poster, during a conference internal to the School of Psychology, University of Nottingham, held in April 2015.

Study 2.

We tested the number of elements presented in the memoranda array for both the easy and hard conditions. Each pilot we run contained a combination of 2, 3 or 4 elements in the memoranda

array for the easy condition and 4, 5, 6 or 7 elements in the hard condition. In the first stages of this test, we included both consonants and vowels in the memoranda array, excluding however any repetition of any letter within the same array. The order of the letters presented was always randomised and never alphabetical. However, after verifying that participants were facilitated in the task by the presence of vowels in the memoranda, we excluded them and used only consonants in the following stages of the testing.

Duration of the memoranda, probe and distractor windows have been tested on a staircase procedure, keeping two of the three elements constant and changing the length of the remaining one. We selected, for each window, the three most suitable durations according to the participants: the criteria of selection for the durations were the easiness of visual processing, the overall difficulty of the trial, the overall pace of the presentation, the transition between two consecutive windows. For example, with regard to the memoranda array window, a too short duration would not allow the participants to read the full array; the increase or decrease of the window length would respectively decrease or increase the difficulty to complete a single trial. Relatively long durations for the memoranda array would lead to a slow-paced task, with a subsequent increase in the chances of loss of attention for the participants. Finally, long durations of each window in a trial would translate in a rough transition between the different windows due to the presence of too many pauses in the processing of the different elements.

For the memoranda array window, we tested durations ranging between 700ms and 2500ms, with increases in steps of 100ms. For the distractor window, we tested durations ranging between 1500m and 3000ms, with increases in steps of 100ms. For the probe window, we tested durations ranging between 300ms and

800ms, with increases in steps of 50ms. For the delay window, we tested durations between 500ms and 2000ms, with increases in steps of 250ms. For the three durations selected in each window, we tested the possible combinations between the different durations and, on the same criteria previously employed, we selected the final duration of each window.

For the letters of both the memoranda array and the probe letter, we initially tested lower characters but, due to possible confusion between letters (for example, the low-case "L" and the capital "I" letters would look the same), we decided to employ only capital letters for the experiment. After the decision of removing vowels, we focused on the size of the characters: this parameter was tested in terms of PsychoPy internal units of measure for letters height (that is, percentage of letter height referenced to the full height of the screen). The final height selected for the letter was 0.135, i.e. 13.5% of letter-to-screen height ratio. In other words, the height of each letter was equivalent to the 13.5% of the total height of the screen on which the letters appeared. The size of the letters was tested in steps ranging between 0.1 and 0.5%, on a total scale between 10% and 25% letter-to-screen height ratio.

The pilot studies in the current experiment have been run only on the emotional condition, while we tested the experimental protocol with both the emotional and neutral (i.e. scrambled) distractors only after the selection of the optimal parameters for each trial.

After the definition of the lengths for each window, a full pilot study have been run on six participants. In this last case, the whole design, containing the 20% of the trials of the full study, have been tested. In this way, we ensured that all the elements worked the way we expected and, in addition, the whole PsychoPy presentation ran seamlessly in all its components. The main target of the last pilot study was to ensure that a difference was actually present between the easy and the hard condition, to confirm that

the engagement of attentional resources was higher in the latter condition. No specific control has been set for the positive Vs negative distractors, since the research questions and the experimental hypotheses were determined before the creation of the specific task timeline, during the design phase.

Study 3.

In the first version of this experiment, we focused on the creation of the written distractors, since we already used the pictures in the previous two studies. We initially tested emotional words written with the first capital letter and the remaining low-case letters. We then tested the words written in full capital letters and in full low-case letters. The same (N=4) people were involved in the three tests, consisting in the presentation of a series of words on screen to judge the best readability of the words. After receiving feedback from them, we decided to use words in lower-case characters, including the first. The main parameters of selection were: easiness to read the words, absence of confounds between high- and low-case letters and overall length of the character string in relation to the time given to read it. This last parameter was taken into account because, in general, low-case characters are shorter in length than capital letters: therefore, a word written in full capital letters resulted longer on the screen than the same word in low-case characters, providing the same font size. All the participants agreed that the best solution to present the distractors was with words formed by low-case characters, followed by words presented in low-case characters with the first capital letter. The least-liked solution was the presentation of words with full capital letters.

We then controlled for the numerical task and the numbers range to use in it. Our aim was to increase slightly the difficulty of the task compared to Study 1, therefore introducing the comparison of

2-digits numbers within the experiment. However, for the sake of comparability of the results across the different studies, we did not want to excessively increase the range of numbers used. For this reason, we tested three different ranges of numbers, one identical to the first, one containing numbers up to 15 and one containing numbers up to 20. Four participants took part in this pilot. In all cases, accuracy rates were beyond 85% for all the participants. We decided then to use a numerical range between 1 and 20, removing however the numbers 1 and 20 to avoid any anticipated response (i.e. showing the number "1" in the first number window would have automatically triggered a response before the presentation of the second number). Through this choice, the design resulted optimized as the task was judged as more challenging; however, it still allowed the direct comparison of the results from studies 1 and 3.

The duration of the single windows in each trial was tested with a similar procedure to the one illustrated in the previous paragraph for study 2. We tested this after selecting the numbers range to administer in the final version of the study, i.e. after deciding the numbers employed ranged between 1 and 20, extremes excluded.

The criteria of selection for the durations were the easiness of visual processing, the overall pace of the presentation and the transition between two consecutive windows. For the first digit window, we tested durations ranging between 700ms and 2500ms, with increases in steps of 100ms. For the distractor window, we tested durations ranging between 1500m and 3000ms, with increases in steps of 100ms. For the probe window, we tested durations ranging between 300ms and 800ms, with increases in steps of 50ms. For the delay window, we tested durations between 500ms and 2000ms, with increases in steps of 250ms. For the three most liked durations selected for each window, we tested all the possible combinations between the different durations and, on

the same criteria previously employed, we selected the final duration of each window. The size of the characters was again tested in terms of PsychoPy internal units of measure for letters height (that is, percentage of letter height referenced to the full height of the screen). The final height selected for the numbers was 0.25, i.e. 25.0% of number-to-screen height ratio. The final height selected for the letters of the emotional words was 0.2, i.e. 20.0% of letter-to-screen height ratio. The size of both the numbers and the letters the numbers was tested in steps ranging between 0.1 and 0.5%, on a total scale between 15% and 30% ratio element-to-screen height ratio. After the definition of the lengths for each window, a first pilot study was designed and run, in which words and pictures were intermixed as distractors. However, due to negative feedback from the participants, we decided to isolate in autonomous blocks the two types of distractors. In the end, a final pilot study has been run on six participants. In this last case, the whole design, containing the 20% of the trials of the full study, has been tested. In this way, we ensured that all the elements worked the way we expected and, in addition, the whole PsychoPy presentation ran seamlessly in all its components.

Study 4

In the first phases of the pilot studies, we controlled for the visual parameters to allow the optimal superimposition of the stimuli. This stage of the piloting required long time to be completed as we manipulated four variables at the same time in two parallel analyses, one per type of stimulus. For the written stimuli, the parameters were size and opacity of the distracting words, size and opacity of the target words. For the pictorial stimuli, the parameters were size and opacity of the distracting pictures, size

and opacity of the target pictures. The reason of the parallel processing was to select a value for the opacity of both types of stimuli, which would allow the clear and optimal perception of each type of stimulus per se and in relation to the other type. This was done to avoid that, for example, selecting too bright pictures might affect the perception of the words in a potential following block (since the order of the blocks was randomized).

For the opacity parameter of both targets and distractors, and for both words and pictures, we adopted a staircase procedure where we considered all possible opacity levels, ranging from 5% to 100%, in increments of 5%. In this case, 100% represented a fully opaque stimulus, 0% represented a fully transparent stimulus (i.e. not visible). The increment or decrement in opacity was however applied to only one of the two elements at a time: for example, if the value changed for the distractor, it remained constant for the target and vice versa. The same criteria were applied for the size of the stimuli. For the pictorial stimuli, the selected values of opacity were 70% for the targets and 50% for the distractors. For the written stimuli, the selected values of opacity were 15% for the distractors and 100% for the targets.

In terms of size of the stimuli, for the pictures, we adopted a staircase procedure with sizes ranging from 0.3 to 0.8 of the total unitary height of the screen (i.e. ranging from 30% to 80% of the height of the screen) in increments of 0.05 or 0.1, as the measure is used in PsychoPy as default. We judged 0.65 being the optimal value for the distractors (i.e. 65% of the total height of the screen) and 0.4 for the targets (i.e. 40% of the total height of the screen). For the words, the staircase procedure ranged between the values of 0.08 and 0.3, in increments between 0.01 and 0.03. We selected 0.20 and 0.13 (i.e. respectively 20% and 13% of the total height of the screen) as the optimal sizes for the distractor and target words respectively.

Once the visual properties of the elements for each stimulus have been defined, we focused on the duration of each window composing a trial. The presentation time for the distractor alone has been chosen through a staircase procedure with duration ranging between 300ms and 1500ms, with increments of 100ms to 200ms; the duration of the superimposed target has been selected through the same procedure. However, we manipulated the duration of only one element at a time (i.e. if the duration on screen of the target was changed, the duration of the distractor remained constant). The same procedure was applied in parallel to both written and pictorial stimuli.

A final pilot study has been run on six participants. In this last case, the whole design, containing the 20% of the trials of the full study, has been tested. In this way, we ensured that all the elements worked the way we expected and, in addition, the whole PsychoPy presentation ran seamlessly in all its components. In this case, we included both congruent and incongruent trials within the same design. Due to the high variance of the data obtained, we decided to split the two conditions (congruent and incongruent matching of targets and distractors) in two separate studies. We then ran another complete pilot study on five more participants to control for the quality of the data obtained and, after the confirmation of a significant reduction of variance in the new data compared to the previous pilot, we decided to keep the two conditions separated.

Study 5

Due to the similar design of Study 5 with the previous experiment, the piloting for the current study required less time. We controlled for the adequate marching of each target with its distractor, in terms of visual appearance, and ran a second pilot study containing the 20% of the trials of the full study. This pilot study

was run on five participants, to control that all the elements worked the way we expected and, in addition, the whole PsychoPy presentation ran seamlessly in all its components.

Acknowledgements.

Despite my visceral refusal for any public display of affection, a thesis focusing on emotions cannot end without a small expression of personal feelings.

I would like to express my immense gratitude to my supervisors, especially to my principal supervisor Deborah Serrien. She helped me grow not only as a student but also as a person, a scientist and a researcher. Without her constant help and guidance, I would not have been able to achieve any milestone throughout this PhD.

I would like to thank all my office mates and in particular Kanad and Hilmar, for their invaluable help on technical matters but above all for having been like a second family during the endless amount of time spent at uni. A sincere thank you to all the people who contributed to this research: all the colleagues helping with the piloting of the experiments and all the participants who took part in them.

I would like to thank my parents and my sister for their constant support. Words cannot express how blessed I feel to have them by my side in any situation. Their constant love and encouragement were the keys to overcome any dark moment, not only during this PhD.

Last but not least, a special thank you to Karla, for turning the second part of this PhD into an incredible life journey.