Electrophysiological correlates of anticipation and emotional memory

TABASSUM, NAZOOL-E

Nazool -e Tabassum

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Abstract

This thesis investigated the role of anticipation as a mediating factor in the Emotion-Enhanced Memory (EEM) phenomenon. Using behavioural and ERP measures, three anticipatory conditions were explored: Informative, No-Cue and Non-Informative. The primary objective was to determine how far the pre-stimulus-Dm (Ps-Dm) effect is a reliable indicator of emotional memory encoding under different levels of anticipation, and if the preparatory process explanation accounts for any effects. This study also aimed to determine if there is an association between anticipatory activity at the pre- and post-stimulus phase, and the related behavioural outcome. One behavioural and three ERP studies were conducted to measure the difference due to memory (Dm) effect during an anticipatory phase. The Dm effect distinguishes between neural activity of subsequently remembered and forgotten items, providing an index of successful encoding. We employed an S1-S2 (Stimulus 1: Cues - Stimulus 2: Pictures) Cueing-Subsequent Memory Paradigm. Upper case letters (O, X, Z) served as cue stimuli (S1). Emotional and neutral images selected from International Affective Picture System (IAPS) were used as S2. Findings revealed a Dm effect for informative as well as for non-informative cue conditions when participants anticipated high-arousal emotionally negative pictures. This effect was found during the 400-600ms time window only when the cue remained on the screen. This effect was not significant for the studies in which the arousal level of anticipated negative pictures was mixed. Moreover, the behavioral findings mirrored the neural activity in this particular study. However, in rest of the studies, behavioral results could not corroborate neural activity. The results of the present set of experiments highlighted that emotional memory might be formed without specific information about the content or valence of imminent pictures.

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Nazool-e Tabassum

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Table of Contents

Abstract **1**

List of Figures **9**

List of Tables **11**

Declarations **12**

Statement of Copyright **13**

Acknowledgments **14**

Chapter 1: General Introduction **15**

1.1 Brief history of theories of emotion 15

1.2 Emotion: Appraisal, Valence, and Arousal. 17

1.3 Memory: Encoding, consolidation, and retrieval. 19

1.4 The subsequent memory paradigm (SMP) 21

1.4.1 Emotion-Enhanced Memory (EEM): Theoretical framework 24

1.4.2 Electrophysiological correlates of encoding and anticipation 26

1.4.3 Elaboration and EEM 29

1.4.4 Anticipation and EEM 30

1.5 Behavioural Procedures and EEM 33

1.5.1 Recall memory 33

1.5.2 Recognition memory 33

1.6 Gender difference and Pre-stimulus activity 34

1.7 Selection of Event-related potential (ERP) 35

1.8 Significance of the issues 36

1.9 Thesis Objective 36

Chapter 2: General Electroencephalography Method **37**

2.1 Overview 37

2.2 EEG/ERP background 37

2.3 Spontaneous EEG versus ERP 38

2.4 Features and characteristics of ERP 39

2.4.1 Signal-to-noise ratio 39

2.4.2 Components 40

2.4.3 Nomenclature 40

2.4.4 Identifying a component 41

2.4.5 Inferences and ERP data 43

2.5 ERP: Hardware and software 43

2.5.1 Stimulus display 43

2.5.2 Data recording and acquisition 44

2.5.3 Amplifiers and Impedance 45
2.5.4 EEG montage and reference electrode 45
2.6 Data analysis 46
2.6.1 ERP: Pre-processing of data 46
2.6.2 Filtering 46
2.6.3 Artefact identification and correction 47
2.6.4 Segmentation/epoch 48
2.6.5 Baseline removal 48
2.6.6 Averaging 48
2.6.7 Re-referencing 49
2.6.8 Statistical analysis 49
2.7 Graphic representation 51
Chapter 3: Role of level of processing in modulating emotional memory 52
3.1 Overview 52
3.2 General Introduction 52
3.3 Experiment 1: Semantic elaboration versus shallow processing 54
3.3.1 Introduction 54
3.3.2 Study 1a: Normative Word Rating Study 56
3.3.3 Study 1b: Shallow vs. Semantic Encoding 63
3.4 Experiment 2: Semantic vs. Self-Referential encoding 69
3.4.1 Introduction 69
3.4.2 Method 74
3.4.3 Results 76
3.4.4 Discussion 78
3.5 General Discussion 79
Chapter 4: Role of anticipation in enhancing emotional memory at behavioral level 81
4.1 Overview 81
4.2 Introduction 81
4.2.1 Anticipation and retention interval 84
4.2.2 Anticipation and remember-know paradigm 85
4.2.3 Rationale of current experiment 86
4.2.4 Study objectives 86
4.3 Method 86
4.3.1 Design 87
4.3.2 Stimuli and Materials 87
4.3.3 Procedure 88

4.3.4 Statistical Analysis 90
4.4 Results 91
4.4.1 Recognition data; Hit-rates, R-hits, K-hits, K-corr-hits and False Alarm 92
4.4.2 Accuracy of Recognition Judgments 93
4.4.3 Pr-Index for overall memory accuracy (HR) 93
4.4.4 Pr-Index for R-judgments (R-hits) 95
4.5 Discussion 97
4.6 Conclusion 100
4.7 Future Directions 100
Chapter 5: Pre-stimulus subsequent memory effects in absence and presence of cues ..101
5.1 Overview 101
5.2 Introduction 101
5.2.1 Preparatory process hypothesis 102
5.2.2 Modulation explanation 104
5.2.3 Random fluctuation hypothesis 105
5.2.4 Preparatory process explanation 106
5.3 Method 109
5.3.1 Participants 109
5.3.2 Design 110
5.3.3 Stimuli and Material 110
5.3.4 Procedure 112
5.3.5 Electrophysiological Data Recording and Processing 115
5.3.6 Electrode clusters 115
5.3.7 Time bins for Picture-Locked ERP Analysis 116
5.3.8 Time bins for Cue-Locked ERP Analysis 116
5.4 Results 117
5.4.1 Behavioural data Analysis 117
5.4.2 Cue-Locked ERP Analysis 121
5.4.3 Picture-Locked ERP Analysis 126
5.5 Discussion 128
5.5.1 Ps-Dm effect during anticipatory phase 128
5.5.2 Emotional anticipation: SPN 130
5.5.3 Picture-related subsequent memory effects 131
5.5.4 Behavioral data 132
5.6 Conclusions 132
5.7 Future directions 132

Chapter 6: Pre-stimulus subsequent memory effects for informative and non-informative cues 134
6.1 Overview 134
6.2 Introduction 134
6.2.1 Role of attention in short and long-term memory formation 139
6.2.2 Anticipation and efficient processing 139
6.2.3 Rationale and aims 140
6.3 Method 141
6.3.1 Participants 141
6.3.2 Design 141
6.3.3 Stimuli and Material 142
6.3.4 Procedure 142
6.3.5 Electrophysiological Data Recording and Processing 143
6.3.6 Electrode clusters 144
6.3.7 Picture-Locked ERP time bins 144
6.3.8 Cue-Locked ERP time bins 144
6.3.9 Reaction Time Analysis 145
6.3.10 Statistical Analysis 145
6.3.11 Cue-Locked Analysis 145
6.3.12 Picture - Locked Analysis 146
6.4 Results 146
6.4.1 Behavioural Data Analysis 146
6.4.2 Cue-Locked ERP Analysis 150
6.4.3 Picture-Locked ERP analysis 153
6.5 Discussion 155
6.6 Conclusion 160
6.7 Future Direction 161
Chapter 7: Anticipation of high arousal emotional stimuli under informative and non-informative cues 162
7.1 Overview 162
7.2 Introduction 162
7.2.1 Emotional memory and arousal 163
7.2.2 Arousal and attention 163
7.2.3 Modulation hypothesis 164
7.2.4 Rationale and Aims 166
7.3 Methods 167

7.3.1 Participants ... 167
7.3.2 Design ... 168
7.3.3 Stimuli and material ... 168
7.3.4 Procedure ... 169
7.3.5 Electrophysiological data recording and processing ... 169
7.3.6 Electrode Clusters ... 170
7.3.7 Time bind for picture locked analysis ... 170
7.3.8 Time bins for cue locked analysis ... 170
7.3.9 Cue-locked Analysis ... 170
7.4 Results ... 171
7.4.1 Behavioural Data Analysis ... 171
7.4.2 Cue-locked ERP Analysis ... 175
7.4.3 Picture- Locked ERP Analysis ... 177
7.5 Discussion ... 178
7.6 Conclusion ... 181
Chapter 8: General Discussion ... 182
8.1 Overview ... 182
8.2 Anticipation and emotional memory ... 182
8.3 Behavioural findings ... 183
8.3.1 Valence ratings ... 184
8.3.2 Reaction time ... 185
8.4 ERP Findings ... 185
8.4.1 Neural activity preceding cue (Pre-stimulus Dm-effect) ... 185
8.4.2 Neural activity following picture (Post-stimulus Dm-effect) ... 190
8.5 Strengths of the experimental work ... 191
8.5.1 Conceptual framework ... 191
8.5.2 Refining of methodology ... 192
8.6 Limitations and Study specific issues ... 192
8.6.1.3.3 Cue-picture time intervals ... 194
8.7 Future Directions ... 195
8.8 Implications ... 197
8.9 Concluding remarks ... 198
Appendices ... 200
Appendix A ... 201
Appendix B ... 202
Appendix C ... 203

Appendix D **204**
Appendix E **205**
Appendix F **206**
Appendix G **207**
Appendix H **208**
Appendix I **211**
Appendix J **213**
Appendix K **214**
Appendix L **216**
Appendix M **217**
Appendix N **218**
Appendix O **220**
Appendix P **221**
Appendix Q **222**
Appendix R **225**
References **226**

List of Figures

Figure 1.1: The valence and arousal dimensions of emotional stimuli 18
Figure 1.2: Subsequent memory paradigm & Subsequent memory effect (SME/Dm effect)22
Figure 2.1: Spontaneous EEG to ERP 38
Figure 2.2: Spontaneous EEG and Frequency bands 39
Figure 2.3: ERP nomenclature 41
Figure 2.4: The 64-channel cap layout with 10/10 system.. 44
Figure 2.5: Experimental set-up for a typical ERP experiment.. 45
Figure 2.6: Electrode cluster schematic.. 51
Figure 3.1: Mean rating scores on qualitative and qualitative dimensions of ANEW words 61
Figure 3.2: Mean scores under shallow and semantic encoding condition -Pilot study. 63
Figure 3.3: A schematic illustration of shallow encoding. 66
Figure 3.4: A schematic illustration of semantic encoding.. 67
Figure 3.5: Mean recall rate by encoding conditions and valence. Error bar represents the standard error of mean.. 68
Figure 3.6: A schematic illustration of self-reference encoding... 76
Figure 3.7: Mean scores on recall memory for self-reference and semantic encoding. 77
Figure 4.1: A schematic illustration of a trial structure for three anticipatory conditions.... 89
Figure 4.2: An illustration of the trial structure for test/retrieval phase. 90
Figure 4.3: Pr-Index for overall memory accuracy: Hit Rates scores (HR)........................... 94
Figure 4.4: Valence wise Pr-Index for recognition memory scores (Hits rates) 95
Figure 4.5: Cue wise Pr-Index for R judgements/ R-hits. 96
Figure 4.6: Valence wise Pr-Index for R judgements/ R-hits. 97
Figure 5.1: Encoding phase- Schematic of the Experimental Trial 113
Figure 5.2:Test phase- Schematic of the Experimental Trial 114
Figure 5.3: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of Valence 119
Figure 5.4: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of cue conditions.. 120
Figure 5.5: ERP waveform and Scalp maps representing cue related activity across picture valence. 123
Figure 5.6: ERP waveform and Scalp maps representing cue related encoding activity across picture valence for 350-600ms time bin.. 125
Figure 6.1: Encoding phase- Schematic of the Experimental Trial 143

Figure 6.2: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of Valence. 148
Figure 6.3: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of cue conditions.. 149
Figure 6.4: ERP waveform and Scalp maps representing cue related encoding activity across picture valence 600-800ms time bin. 152
Figure 6.5: ERP waveform and Scalp maps representing picture related encoding activity for 400-1000ms time bin. 155
Figure 7.1: Recognition memory performance for Hit-rates, R-hits and K-corr-hits as a function of Valence 173
Figure 7.2: Recognition memory performance for Hit-rates, R-hits and K-corr-hits as a function of Cue condition 174
Figure 7.3: ERP waveform representing cue related encoding activity across picture valence for 1000-3000ms time bin. 176

List of Tables

Table 3.1: Correlation coefficients between qualitative dimensions of ANEW words. 62

Table 3.2: Mean scores of negative and neutral words recalled under Shallow and Semantic encoding conditions 68

Table 4.1: Proportions of recognition memory performance and its sub-components as a function of cue condition, and picture valence 93

Table 5.1: Number of participants excluded from the data analysis with reasons for exclusion 109

Table 5.2: Proportions of “Old” responses on the recognition memory test as a function of Cue condition, Picture Valence and memory performance 118

Table 6.1: Number of participants excluded from the data analysis with identity code and reasons for exclusion 141

Table 6.2: Proportions of “Old” responses on the recognition memory test as a function of Cue condition, Picture Valence and memory performance 147

Table 7.1: Table shows the number of participants excluded from the data analysis and Criteria for Removal 168

Table 7.2: Mean scores on arousal and valence of negative and neutral pictures selected from IAPS and GAPED database for the current study 169

Table 7.3: Proportions of “Old” responses on the recognition memory test as a function of Cue condition, Picture Valence and memory performance 172

Declarations

This thesis is based on research carried out at the Department of Psychology, at the University of Durham. No part of this thesis has been previously submitted for a degree at this or any other institution. The work here is my own.

Poster Presentation

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BNA: Festival of Neuroscience, Edinburgh, United Kingdom (2015). Pre-stimulus subsequent memory enhancements: The role of random fluctuations in attention.

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Chapter 1: General Introduction

Events that evoke emotional reactions are more likely to be remembered better than events that lack emotional reactions (Kensinger, 2009). For example, events such as the death of Princesses Diana in 1997, the destruction of the World Trade Centre in New York in 2001, and the bombings in London in 2005, are often recalled with an exceptional degree of vividness and clarity (Elaine, 2008). Similarly, personal emotional memories of the autobiographical past, such as the death of a loved one or the breakup of a relationship, are also recalled in remarkable detail. These examples of enhanced memory for both public and individual-level events reveal how powerful an influence emotion can exert on memory (Bennion, Ford, Murray, & Kensinger, 2013).

The beneficial effects of emotion on memory have also been demonstrated in controlled laboratory investigations. For instance, participants presented with a series of pictures tend to remember positive and negative pictures more than neutral ones (Dolcos & Cabeza, 2002; Dolcos, LaBar, & Cabeza, 2004; Pottage & Schaefer, 2012; Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014). This memory advantage has been shown to occur with a variety of emotional stimuli, such as pictures, words, sentences, and narrated slide shows (Bradley, Greenwald, Petry, & Lang, 1992; Cahill & McGaugh, 1995; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002). The increased likelihood of remembering emotional information is referred to as the Emotion-Enhanced Memory (EEM) effect, which is the primary focus of this thesis.

1.1 Brief history of theories of emotion

Research on emotion has a rich history, the first well-known account of emotions originated by William James (1884) and Carl Lange (1887, as cited in Myers, 2004). Their theory posited that emotion is the result of physiological responses to the event rather than the perception of an event. In terms of the sequence of events, the individual experiences bodily change first, such as fast breathing, heartbeat, and sweaty hands and then experiences the emotion. William James's theory was criticised by Walter Cannon in 1927 for two reasons: one, emotion occurs even if the brain is not able to get information about the physiological responses, and two, different emotions might be felt by same bodily responses. Cannon's theory was later expanded on by physiologist Philip Bard during the 1930s. According to the Cannon-Bard theory of emotion, we feel emotions and experience physiological reactions such as sweating, trembling, and muscle tension, simultaneously. Later, appraisal theories of emotion gained importance. Many years later, two psychologists called Stanley Schachter and Jerome Singer, suggested that experiencing an emotion is a combination of both physiological response and an interpretation of the bodily response by considering the particular situation (Schachter & Singer, 1962). A number of theories were presented later to understand emotion and its relation to other cognitive factors. In the next few paragraphs, the history of the development of some important theoretical accounts related to emotion and its impact on memory are discussed. The effect of emotion on memory led William James in 1890 to propose that exceptionally emotional events leave "a scar upon the cerebral tissues" (James, 1890). Later on, a number of theories highlighted the immediate and future adaptive role of emotion for organisms. From an evolutionary perspective, emotions were defined as a psychological mechanism which prepares the organism to solve current and future adaptive problems such as escaping from danger and predators, finding food, shelter, mates and delivering of genes to one's offspring (Cahill & McGaugh, 1998a; Hamann, 2001; LeDoux, 1995). Hence, the formation of memory is an integral part of the adaptive function of emotion. The link between emotion and memory came under intensive investigation in the ninetieth century. In 1908, Robert Yerkes and John Dodson proposed a relationship between emotional arousal and its effect on different task performance. They posited that moderate levels of emotional arousal enhance performance (Dodson, 1915). Their investigation gave rise to a wealth of research and remains significant historically even today. In the similar vein, a comprehensive and robust account on emotional arousal was proposed by Easterbrook (1959) in his Cue Utilization Hypothesis which is often applied to emotional memories. He postulated that emotional arousal is related to attention and the level of arousal determines the focus of attention by narrowing it (Easterbrook, 1959). A high arousing emotional event will be encoded in memory because it narrows the attention of the individual towards the central details (cues) of the event (Scherer & Oshinsky, 1977). In such cases, peripheral details of the event are not attended to and consequently not stored in the memory, while the information that is central to the source of emotional arousal will be stored. Easterbrook's hypothesis was well-supported by research using both humans and animal models (Burke, Heuer, & Reisberg, 1992; Christianson, Loftus, Loftus, & Hoffman, 1989; Kensinger & Schacter, 2006). From Easterbrook's perspective, Sarason and Stroops (1978) proposed an investigation of eyewitness testimony, but could not actually pursue it (Sarason & Stoops, 1978). Few others proposed that during arousal, subjects may focus more attention on the internal processes which might lead to the formation of lasting memories (Pennybaker, 1983; Siegel & Loftus, 1978). However, Easterbrook's hypothesis in eyewitness testimony was tested first time in their study. Later, 'weapon effect phenomenon was highlighted as an important encoding factor which influences the memory of the crime (Loftus, Loftus, & Messo, 1987). The weapon focus phenomenon proposed that attention of an eyewitness is focused on the weapon (emotionally arousing) at the expense of memory for other details of the crime (Loftus et al., 1987). Right around a century after William James' proposed the concept of 'cerebral scars', Brown & Kulik (1977) portrayed emotional memories as a photo brought with a flashbulb, bringing about the term "flashbulb memories." Brown and Kulik posited that 'Flashbulb memories' are extremely vivid and become a permanent part of memory after some unexpected and emotionally arousing event occurs. The assassinations of Abraham Lincoln (Colegrove, 1899), John F. Kennedy, Martin Luther King, Jr. (Brown & Kulik, 1977) and attack on the World Trade Center in September 2001 are a few historical events which led to flashbulb memories. This phenomenon generated an enormous amount of research studies which challenged the properties, occurrence and accuracy of the flashbulb memories. For instance, studies have found that detail of flashbulb memories declines as well as distorts over time (Greenberg, 2004; Schmidt, 2004). Moreover, enhanced detail of flashbulb memories is more associated with elaborative rehearsal (Talarico & Rubin, 2007) than with special neural mechanisms emphasised by Brown and Kulik (1977). There is compelling evidence that emotions have the capacity to alter the subjective feelings linked to the emotional memories (Phelps, 2006).

1.2 Emotion: Appraisal, Valence, and Arousal.

Before entering into a systematic and scientific review of EEM, it is important to understand how emotion and memory are each conceptualized, and also how their salient characteristics may interact with one another. Both emotion and memory are not single constructs, but rather comprise a host of processes that together allow our prior experiences to mould current behavior and thought (Kensinger, 2009). Therefore, a satisfactory explanation of EEM requires highlighting the aspects of emotion and memory that have been explored independently, as well as in combination within the emotional memory literature. Appraisal theorists posit that emotions arise as a result of evaluating the environment on the basis of criteria such as novelty, predictability, significance to one's own goals, agency, and compatibility with social and personal standards (Scherer, 1984; Smith & Ellsworth, 1985). Thus, emotional evaluation is the central defining feature of the emotional phenomenon, whereby emotions are perceived and categorized according to their intensity and directionality.

To fully comprehend how emotion impacts memory, it is necessary to understand the dimensions of emotion and how they have been conceptualized and operationalized in the emotional memory literature. According to a widely accepted framework, emotions have two dimensions: valence and arousal (Lang, Greenwald, Bradley, & Hamm, 1993; Russell, 1980). Valence merely denotes the direction of the emotion (whether it is positive or negative), and arousal refers to the intensity of the physiological or psychological response to a positive or negative emotion (Kuppens, Tuerlinckx, Russell, & Barrett, 2013).

Previous research has shown that valence is linked to behavioural outcomes. For example, negative valence is generally related to withdrawal, escape, refusal, and aggression; while positive valence is linked to approach, tolerance, and acquisition (Scherrer, Schorr, & Johnstone, 2001). Arousal ranges from calm or tired out to excited or tense. Whereas feeling excited or tense represent high arousal states of positive and negative emotions respectively, feeling calm or tired out constitute the low arousal states of these emotions (Kensinger, 2004). Neutral stimuli/events are conceptualized as those who neither represent any specific direction of positive or negative emotion (no valence) nor are they high in arousal such as excited or agitated are (Kensinger, 2004).

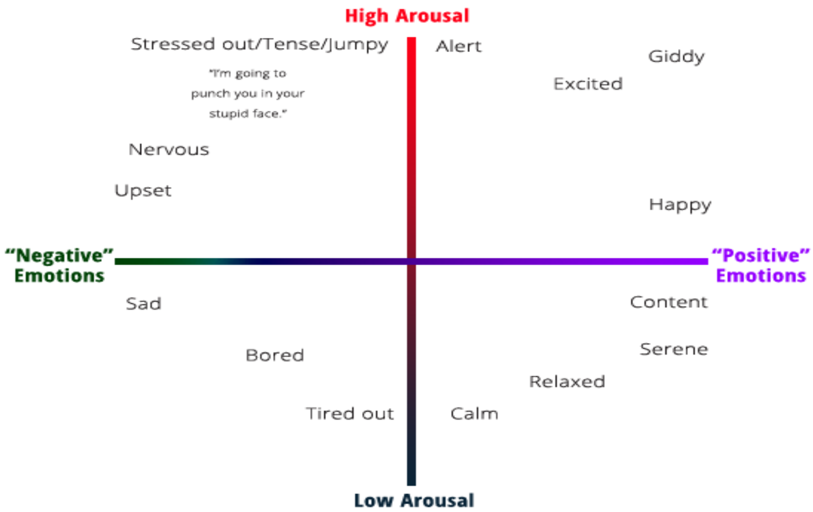


Figure 1.1: The valence and arousal dimensions of emotional stimuli

One major challenge in emotional memory research is inducing an emotional reaction in participants without eliciting an explicit appraisal contribution from them (Fox, 1991; Kensinger, 2009a). A widely used method for emotional induction involves the presentation of emotionally salient pictures, words, or sounds. Extensively used databases in emotional memory research include the 'International Affective Picture Systems (IAPS)' and the 'Geneva affective picture database: GAPED' (Dan-Glauser & Scherer, 2011) for images, (Lang, Bradley & Cuthbert, 2008) and the Affective Norms for English Words (ANEW) database for verbal material (Bradley & Lang, 1999a). IAPS and ANEW databases rely on the theoretical background of a three-dimensional affective space construct (Bradley & Lang, 1994; Mehrabian & Russell, 1974; Osgood, 1969; Russell & Mehrabian, 1977). As such, they provide normative ratings of emotion in the valence, arousal, and dominance dimensions using a specific rating scale known as the Self-Assessment Manikin (SAM), devised by Lange (1980). This collection of affective pictures and words with normative ratings provides a standardized set of material for the study of emotion and attention, thereby enabling better experimental control, replication, and comparison across emotion-related studies. The Geneva Affective Picture Database (GAPD) is complementary to IAPS and has been developed only recently (Dan-Glauser & Scherer, 2011). Similar to IAPS, it provides normative ratings on the valence and arousal dimensions, as well as ratings on the legal and moral/ethical acceptability for all the sets of negative (human, animal, snakes/spiders), neutral, and positive thematic pictures (Dan-Glauser & Scherer, 2011).

1.3 Memory: Encoding, consolidation, and retrieval.

Analogous to emotion, memory is not a single construct, but comprises a set of processes used to acquire, store, retain and later retrieve information (Elaine, 2008). A tremendous amount of behavioural research has investigated the effects of emotion on multiple stages of memory, i.e., encoding (formation of the first memory trace), consolidation (strengthening of the trace) and retrieval (see Bradley, Greenwald, Petry, & Lang, 1992; Talmi, Luk, McGarry, & Moscovitch, 2007). The effects of emotion on memory have also been studied for short-term, long-term, implicit, and explicit memory processes. In this thesis, emotional memory enhancement is specifically studied as an effect of emotion on long-term declarative memory. Therefore, the effect of emotion on long-term memory will be the primary focus of this research project.

Encoding is a crucial first step in creating a new memory (Post et al., 1998). The encoding process begins when attention is placed on a perceived event/stimulus, which allows that event/stimulus to be converted into a memory trace that can be stored within the brain (Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004). Prior research has shown that encoding is not a unified process. Instead, the perceptual and conceptual features, as well as the contextual details and self-generated thoughts that pertain to the current episode, are co-activated during encoding to give rise to new memories (Richardson, Strange, & Dolan, 2004). Many of the effects of emotion on encoding seem to be due to the arousing nature of the stimulus (i.e., how calming or exciting a stimulus is) rather than to its valence (Guderian, Schott, Richardson-Klavehn, & Düzel, 2009; Richardson et al., 2004). During encoding, emotional arousal selectively narrows our attention to encode the emotionally salient information, to guide our engagement of elaborative processes (Hamann, 2001), and to spare our cognitive resources from being depleted by the processing of less relevant cues (Christianson & Loftus, 1991; Easterbrook, 1959; Ohman, Flykt, & Esteves, 2001; Reisberg and Heuer, 1992). One focus of this thesis revolves around the role of encoding, and specifically, whether or not anticipatory processes facilitate the encoding of emotional memories.

Emotion also affects the way that information is stabilized after encoding, i.e., the consolidation phase (Cahill & McGaugh, 1998; Labar & Cabeza, 2006c). Consolidation is seen as a neural process that involves gradually converting information from short-term memory into long-term memory (Hermans et al., 2014). At the cellular level, the process of consolidation is thought to involves long-term potentiation, which occurs in the hippocampus (a medial temporal lobe structure) when the same group of neurons fire together so often that they become permanently sensitized to each other, and consequently, are more likely to fire together in the future when the information is recalled (Eichenbaum, 2012; Nelson, 1995). As a neuronal pathway, or neural network, is traversed over and over again, an enduring pattern is engraved, and neural messages are more likely to flow along such familiar paths of least resistance (McGaugh, 2000). As a result, memory for that information is recalled with greater ease and accuracy (Brown and Kulik, 1977). This cellular mechanism is believed to play a major role in learning and memory processes.

The neural mechanism underlying emotional memory consolidation involves stress hormones, which lead to elevated levels of blood sugar and arousal, and facilitate the formation and strengthening of a memory trace. Activity in the amygdala, a key structure in consolidation, has been shown to modulate other memory systems, such as the hippocampus (Cahill & McGaugh, 1998). Consolidation is discussed in more detail below under the section: Modulation model of emotional memory.

Once memories are formed through consolidation, the information previously encoded and consolidated can be recalled. This phase is known as 'retrieval' (Slotnick, 2012). Memory retrieval requires revisiting the neural pathways formed during encoding and the strength of those pathways (consolidation) determines how quickly the memory can be recalled. Retrieval performance is assessed via recognition and recall testing methods in experimental studies. Recognition testing is usually considered to be "superior" (i.e., more effective) to recall testing, in that it requires only a simple familiarity decision, whereas recall of an item from memory requires a two-stage process: one involving the search and retrieval of an event from memory, and the other a familiarity decision about the retrieved information (Slotnick, 2012). To provide a more precise explanation, dual process theories of recognition memory have been proposed where recognized items can be classified as "recollected" or "familiar" based on Remember-Know judgments (Mandler, 1980). Recollection involves consciously retrieving contextual details that were associated with the item at the time of encoding, whereas familiarity involves knowing that the item was presented before, even though no specific information about its prior occurrence can be recalled (Dunn, 2004). In emotional memory literature, the Remember-Know judgment task is frequently employed to assess the strength and accuracy of recognized emotional memories (Sharot, Delgado, & Phelps, 2004; Sharot, Yonelinas, & Andrew, 2008)

Understanding why the EEM effect occurs requires investigating how emotion-related cognitive processes modulate the encoding of emotional information. One neural indicator of encoding processes at work is referred to as the 'Subsequent memory effect' (SME) or alternatively the 'Difference due to memory' (Dm effect) in the neuroimaging literature. Emotional stimuli can facilitate encoding and enhance the degree of this effect. How this emotional modulation influences the value of Dm is explained below, using the description of a standard protocol—the subsequent memory paradigm (SMP)—that is employed to assess SME in emotional memory research.

1.4 The subsequent memory paradigm (SMP)

The classical version of this paradigm consists of two phases: the study phase and the test phase. During the study phase, Event-related potential (ERP) activity, typically measured as an electroencephalogram (EEG), is recorded while participants view pictures/words according to the given experimental task. During the test phase, one's memory (recall or recognition) is tested for the items presented in the study phase. The activity recorded during the study phase for each stimulus is classified as 'remembered' or 'forgotten', depending on the memory performance (see figure 1.2 A). The Dm effect is separately calculated for emotionally negative (remembered emotional stimuli – forgotten emotional stimuli = Emotional Dm) and neutral stimuli (remembered neutral stimuli – forgotten neutral stimuli = Neutral Dm). The neutral Dm is subtracted from the emotional Dm to get a reliable modulatory effect of emotion on memory (see figure 1.2 B). The contrast between brain activity (Dolcos & Denkova, 2014) for the subsequently remembered and forgotten items (SME/Dm effect) reflects successful versus unsuccessful encoding of information in the memory.

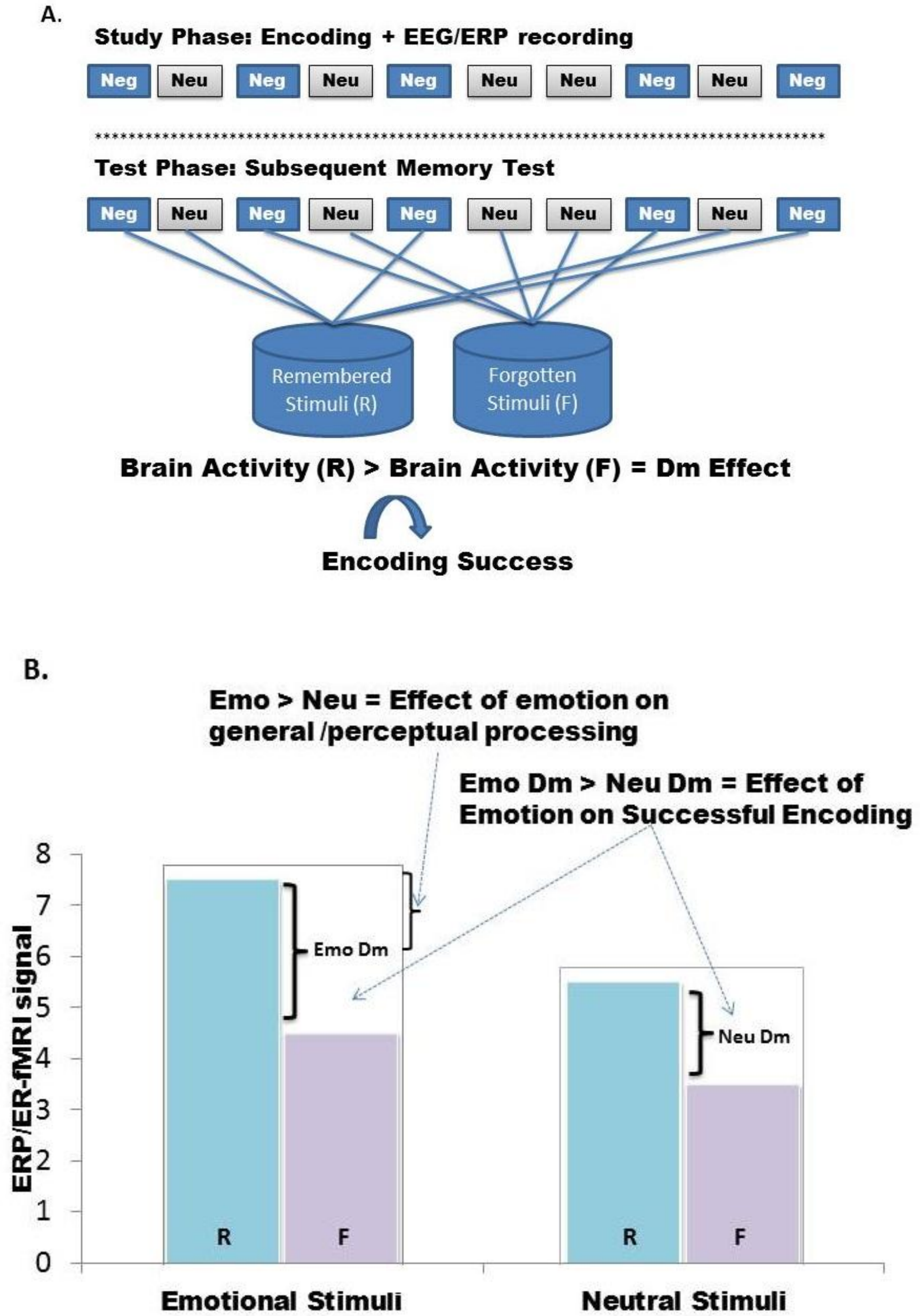


Figure 1.2*: Subsequent memory paradigm & Subsequent memory effect (SME/Dm effect)*

A) In a typical ERP study encoding related EEG/ERP activity is recorded while subjects passively /actively view the emotional and neutral images. After a retention interval lasting from minutes to hours, subjects' memory is tested. EEG/ERP can also be recorded during the test phase. Otherwise, ERP activity, recorded at encoding phase, is sorted into remembered and forgotten pictures for further statistical analysis for Dm effect. B) this figure shows how difference due to memory is calculated based on subjects' performance. Reprinted from, "The impact of emotion on memory: evidence from brain imaging studies" by Dolcos, F. p.26, Copyright©2009. Used with permission of the author and VDM Verlag Dr. Muller Aktiengesellschaft & Co.KG

A significant feature of the subsequent memory paradigm is that it can be used to do simpler comparisons: emotional vs. neutral items and remembered versus forgotten items. Event-related potential (ERP) studies identified the *emotion effect* as the difference in amplitude between the ERPs for emotional and neutral stimuli (e.g., emotional stimuli – neutral stimuli = Dm) (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Johnston, Miller, & Burleson, 1986; Naumann, Maier, Diedrich, Becker, & Bartussek, 1997). On the other hand, the difference between the amplitude of remembered and forgotten items can be called the *memory effect* (remembered stimuli – forgotten stimuli = Dm). The paradigm is particularly informative, as it provides separate electrophysiological measures of both the effects of memory and emotion, allowing them to be studied individually.

In imaging studies, the emotion effect is expressed as a greater activity for emotional vs. neutral stimuli in the amygdala and the hippocampus – regions of the brain responsible for emotional processing. Activity in these regions occurs during tasks that involve the evaluation of the emotional content of various stimuli (e.g., while rating stimuli for pleasantness) (Dolcos et al., 2004). The emotion effect identified in ERP and hemodynamic studies are assumed to have similar neural generators. Since the spatial resolution of ERP does not allow precise identification of the neural generators of the ERP emotion effect, this effect has been characterized in terms of ERP components (e.g., timing, amplitude) and only roughly in terms of their scalp Anteriority (e.g., anterior-frontal vs posterior/occipital, etc) (Dolcos et al., 2004). For example, the ERP emotion effect is mostly consistent 300ms following stimulus onset and is maximal over the frontal and parietal scalp Anteriority (Dolcos & Cabeza, 2002). The neural generators of the ERP emotion effect reflect interactions between the amygdala and the cortical regions (e.g. lateral and medial prefrontal and parietal-occipital areas) that are typically associated with emotional processing in animals and humans (LeDoux, 2000; McGaugh, 2004).

Memory-related differences in brain activity can be assessed during both encoding (SME) and retrieval stages. During encoding, the brain regions most typically associated with memory function are the prefrontal cortex (PFC) and the medial temporal lobe (MTL) (Eichenbaum, 2000; Moscovitch, 1992; Squire & Zola-Morgan, 1991). In neuroimaging studies, greater activity in these regions is observed during encoding for remembered vs. forgotten stimuli (SME) (Paller & Wagner, 2002; Rugg, Otten, & Henson, 2002). However, few studies have focused on comparing brain activity for remembered and forgotten items during retrieval success (Prince, Daselaar, & Cabeza, 2005; Weis, Klaver, Reul, Elger, & Fernández, 2004).

1.4.1 Emotion-Enhanced Memory (EEM): Theoretical framework

According to the general consensus, Emotion-enhanced memory (EEM) might be caused by a facilitation of neural plasticity or cortical remapping (Post et al., 1998). Plasticity is the term used to describe the fact that neural networks remain open to change, and can be modified by events and experiences. For this reason, when emotional events are encountered, already existing neural pathways are altered in order to adapt to new information, thereby enhancing the encoding efficiency for emotional events - leading ultimately to long-lasting memories (LaBar & Cabeza, 2006b; LeDoux, 1993; Quirk, Armony, Repa, Li & LeDoux, 1996; Tully & Bolshakov, 2010).

EEM has been analysed at two levels: cognitive and neural. The cognitive level analysis suggests that memory for emotional information may be enhanced for the same reasons as any other type of information. In particular, emotional stimuli tend to be highly related to one another, and also tend to be more distinct and elaborate. These cognitive factors contribute to EEM (Talmi, Luk, McGarry, & Moscovitch, 2007). At the neural level, stress hormones and amygdala-hippocampus interactions boost memory for emotional information (Gallagher, Kapp, Musty, & Driscoll, 1977).

The present study seeks to answer questions like, "Does the magnitude of emotional arousal play a key role in enhancing memory in addition to the emotional valence of the stimuli"? If so, what is the relative contribution of both? Exactly how do they interact to influence memory, and at what stages does this occur? A review of studies on the effect of arousal and valence is necessary to understand the background to these questions.

According to a number of past studies, much like valence, arousal plays a critical role in EEM. However, attempts at finding the relative contribution of arousal over valence have resulted in mixed findings. Although EEM has been found largely for high-arousal positive and negative stimuli (Cahill, Babinsky, Markowitsch, & McGaugh, 1995; Cahill & McGaugh, 1998), other studies have reported memory-enhancing effects for even non-arousing negative and positive stimuli (Kensinger & Corkin, 2003; Ochsner, 2000). These mixed results indicate that different processes work to enhance memory with respect to valence and arousal.

At present, two models have been proposed to explain the relative contribution of arousal and valence to the EEM phenomenon: the modulation model (Cahill & McGaugh, 1998; McGaugh, 2004; Schmidt & Saari, 2007) and the mediation model (Talmi, 2013). The modulation model, based largely on studies with animals, suggests that emotional arousal, amygdala activation, and consolidation are central to emotional memory formation (Cahill

& McGaugh, 1998; McGaugh, 2000, 2004; Schmidt & Saari, 2007). This highlights the role of the encoding or consolidation phase of memory formation.

Stress hormones are a key factor in the modulation model, as they enable more efficient consolidation of memory traces (McGaugh, 2004). According to this model, physiological arousal during an emotional episode causes the release of the stress hormones adrenaline and cortisol. These hormones affect the basolateral amygdala and its interaction with the hippocampus (Dolcos et al., 2004; Kensinger, 2009b; LaBar & Cabeza, 2006a, 2006b; Wolf, 2008).

Additionally, the modulation model is further supported by studies measuring recall time. Since emotional memory consolidation takes hours, EEM emerges in a stronger and more consistent manner after longer retention intervals (Kleinsmith & Kaplan, 1963; Schwarze, Bingel, & Sommer, 2012; Sharot, Verfaellie, & Yonelinas, 2007). Using fMRI, Kensinger and Corkin (2004) found that activation of the amygdala and hippocampus correlated with the encoded arousing words that were later remembered. Their findings suggest that the amygdala-hippocampal network might explain the enhanced explicit memory for emotionally arousing stimuli.

Despite providing a parsimonious explanation for many memory phenomena, the modulation model only gives a fragmented explanation of emotional memory. First, if stress caused by emotional arousal causes enhanced memory, then memory should also be enhanced for neutral items when they are presented in close succession with emotionally arousing stimuli. However, it has been observed that memory for neutral items remains unchanged, or in some cases, even impaired (Talmi, 2013; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008). Second, the role of consolidation is also questionable, as empirical data support the view that emotions enhance memory even when memory is tested immediately after a short distractor task before consolidation can take place (A Schaefer, Pottage, & Rickart, 2011; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008; Talmi, Luk, McGarry, & Moscovitch, 2007; Talmi & McGarry, 2012; Talmi, Schimmack, Paterson, & Moscovitch, 2007). Third, the modulation model focuses *only* on the consolidation phase, thereby ignoring the role of the earliest stage of memory, i.e., encoding (Talmi, 2013; Talmi et al., 2008).

The other explanation for EEM comes from the mediation model (Talmi, 2013), which emphasizes the role of the cognitive features of emotional stimuli, such as semantic relatedness, distinctiveness, and attentional resources. In contrast to the modulation model, the mediation model focuses on the cognitive and neural processes that occur immediately after emotional events, i.e., before consolidation takes place. According to this model, emotional events/stimuli engage cognitive processes, such as attention, to a greater extent than neutral stimuli (Kensinger, 2004; Kern, Libkuman, & Otani, 2005; Sharot & Phelps, 2004; Talmi, Schimmack, Paterson, & Moscovitch, 2007) and are well organized (Dewhurst & Parry, 2000; Talmi & Moscovitch, 2004; Talmi, Schimmack, et al., 2007; Talmi, 2013), and more distinctive (Schmidt & Saari, 2007; Talmi, Schimmack, et al., 2007) than neutral stimuli, and hence facilitate the formation of long-lasting memories. However, this model does not claim to replace the modulation hypothesis but instead is thought of as being complementary to it (Talmi, 2013). While the modulation hypothesis elucidates the behavioural and neural changes between immediate and delayed memory, the mediation hypothesis highlights the encoding and retrieval processes for early effects of emotion, and their subsequent modulation of, memory (Talmi, 2013).

It is likely that in addition to benefits stemming from relatedness and distinctiveness, emotional items also benefit from elaborative or deep encoding. Thus, another possible mechanism for explaining EEM calls upon the elaborative processing explanation of emotional stimuli. What follows is a literature review related to elaborative encoding and emotional anticipation and its connection to EEM.

1.4.2 Electrophysiological correlates of encoding and anticipation

Mainly four ERP components are under investigation in the current project: The Dm effect, the Pre-stimulus Dm effect and Stimulus Preceding Negativity (SPN) and Contingent Negative variation (CNV). Two of the components; the Dm effect and the pre-stimulus Dm effect are the primary focus of the current project as they reflect encoding of emotional memories. Other components such as SPN and CNV are secondary to the current project. SPN and CNV are related to emotional anticipation and the properties of cues respectively.

1.4.2.1 The Dm Effect

The ERP component which is an index of successful encoding is referred to as “Dm effect” (Paller & Wagner, 2002) A large number of ERP studies have revealed electrophysiological correlates of encoding of emotional stimuli (Dolcos & Cabeza, 2002; Duarte, Ranganath, Winward, Hayward, & Knight, 2004; Mangels, Picton, & Craik, 2001; Otten, Sveen, & Quayle, 2007). The Dm effect is also named as the subsequent memory effect (SME) and defined as the difference between the neural activity of successfully remembered and forgotten stimuli. This difference has been captured as a more positive gong deflection in the range of 400-800 millisecond time window, largely over centroparietal (Fabiani, Karis, & Donchin, 1990) and a frontocentral (Friedman & Trott, 2000) scalp sites. With regards to the functional significance of Dm effect, it reflects the remembered stimuli engages more attention due to the processing of information at a deeper level which enhances elaboration and hence facilitates memory formation (Paller & Wagner, 2002). Elaborative or meaning-based processing is known to promote successful memory under most testing conditions (Craik & Lockhart, 1972). A number of other studies in the literature have demonstrated that that semantic processing of information leads to memory formation (Otten, Henson, & Rugg, 2001; Otten et al., 2007) which supports the functional interpretation that Dm effect represents increased elaboration. In few studies, Dm effect has been reported quite earlier say before 400ms and after 800ms time window as well (Kim, Vallesi, Picton, & Tulving, 2009; Mangels et al., 2001). The earlier effects represent attentional engagement through early perceptual processes and facilities (Duarte et al., 2004). In contrast, late Dm effects are linked to working memory processes which sustain information to aid in memory formation memory formation (Mangels et al., 2001). One distinction need to be highlighted here is that Dm effect discussed above is recoded during the encoding phase of the study after participants are presented with stimuli: pictures or words.

1.4.2.2 Pre-stimulus Dm effect

Pre-stimulus Dm effect (Ps-Dm effect) is a recent phenomenon linked to the anticipation of emotional stimuli. Just like Dm effect described above, it is defined as the difference between the remembered and forgotten neural activity, however, contrary to Dm effect, it is manifested in response to the emotional cue, not to emotional stimulus itself. Pre-stimulus Dm effect provides an other insight in emotional memory formation as it showed that successful encoding also relies on brain activity prior to encoding process in response to cues only. Otten et al. (2006, 2010) first time reported that there is a significant difference between the neural activity of subsequently remembered and forgotten words during the pre-stimulus period of the study phase. In a functional magnetic resonance imaging (fMRI) study, Mackiewicz (2006) observed subsequent memory-related activation in the dorsal amygdala and anterior hippocampus in responses to aversive cues. Later, Park and Rugg (2010) found significant memory related differences in the level of hippocampal BOLD activity during the cue to item time interval. Few other studies reported that pre-stimulus or anticipatory brain activity is linked to reward anticipation alongside memory formation (Gruber and Otten, 2010; Gruber et al., 2013). A number of studies have found that pre-stimulus Dm effects during spectral (oscillatory) activity even without informative cues.

Pre-stimulus Dm effects reported in the literature are guided by the finding of Galli's study conducted in 2011. The latency of the Ps-Dm has an onset around 400ms to 1500ms. ERPs related to remembered items appeared as a positive-going deflection largest over right Centro parietal scalp sites and present from 300 ms after cue onset until the appearance of the unpleasant picture and in an emotion regulation study it appeared with more positive-going over right posterior scalp sites (Galli, Wolpe, & Otten, 2011).

Anticipatory brain activity not only relates to the perceptual intake of an emotional event but also to the likelihood that the event will be encoded into long-term memory. Neural activity before an emotional event has been found to predict whether the event will later be remembered (Mackiewicz et al., 2006; Galli et al., 2011; Padovani et al., 2011). Anticipatory activity is particularly relevant for the encoding of unpleasant events (Mackiewicz et al., 2006; Galli et al., 2011), especially in women (Galli et al., 2011). Anticipatory activity may play a role in the preparation to process an impending aversive event in an emotional manner, which in turn affects encoding into long-term memory. This mechanism may be particularly evident in women due to enhanced emotional responsiveness (Bradley & Lang, 2007; Gard & Kring, 2007).

1.4.2.3 Stimulus-Preceding Negativity (SPN)

A related ERP component largely ignored in the available literature on Ps-Dm effect studies is Stimulus-Preceding Negativity (SPN). SPN is an ERP component, which is considered an index of emotional anticipation (Boxtel, Geert, & Böcker, 2004; Schupp, Junghofer, Weike, & Hamm, 2003). The latency of this ERP component is conventionally 200ms prior to the picture display. It is assumed that if the upcoming stimulus is predictive and emotional in nature, SPN is larger over right interior scalp site and characterized by a negative slow wave. It is also known as a non-motor preparatory response because no movement is required during the waiting interval (Brunia & Damen, 1988) Manifestation of SPN is not just confined to the emotional stimuli rather there is the class of SPNs related to different stimuli. For instance, SPN is seen in response to the stimuli which provide information about the results (KR), instructions for a task in hand and probe stimuli used for matching the performance also (Brunia, Van Boxtel, & Böcker, 2012; Luck & Kappenman, 2012). SPN has been taken under investigation as an index of emotional anticipation for those trials where participants are able to predict the valence of upcoming pictures. Moreover, an attempt has been made to corroborate relevant concept and methodology of cortical measures of anticipation to fully comprehend the nature of Ps-Dm effect.

1.4.2.4 Contingent Negative Variation (CNV)

SPN is not the only ERP component related to anticipation rather there are two more slow waves that reflect anticipatory process, that is, Contingent Negative Variation (CNV) and Bereitschaftspotential (BP) waves. BP is a slow negative going waves which show itself up prior to the execution of a voluntary movement such as Button press responses (Brunia & Damen, 1988; Brunia et al., 2012). CNV is a slow negative wave which builds up during the Cue (S1) Picture (S2) time interval when S1 warns about the occurrence of S2 in few seconds. The instruction to respond to the S2 is a crucial factor in CNV. CNV is considered to be related to motor preparation. However, it is not the only factor, rather maintained of attention and cue properties are few other factors related to CNV (Leuthold, Sommer, & Ulrich, 2004). Preparatory activity can be observed in any ERP study, before the occurrence of stimuli. CNV waves are is differentially distributed over the scalp depending upon the type of task/instructions involved (Brunia et al., 2012). In the current project, ERP waves related to the cue presentation have been explored. No specific hypothesis was formulated related to CNV due to its exploratory purpose in the current investigation. CNV related activity in the current project was captured in the time window where the cue remained on the screen ~0-1000ms specifically. The analysis focused on the main effect of the cue and its interaction with valence or memory.

1.4.3 Elaboration and EEM

Human memory is fundamentally associative, meaning that a new piece of information is remembered better if it can be associated with previously acquired knowledge that is already firmly anchored in memory (Esteves, Parra, Dimberg, & Ohman, 1994). Encoding can be improved by the organization of memory — a strategy called elaboration, in which new pieces of information are associated with other information already recorded in long-term memory, thus incorporating them into a broader, coherent narrative that is already familiar. An example of elaboration is the use of mnemonics (Schmidt, 2012), which are verbal, visual or auditory associations with other, easy-to-remember constructs, that can then be related back to the data to be remembered.

Elaborative processing emphasizes meaning and associations at the time of encoding of stimuli/events (Craik & Tulving, 1975; Lockhart & Craik, 1990). The more personally meaningful the association is, the more effective the subsequent encoding and consolidation (Bellezza, 1984; Brown, Keenan, & Potts, 1986; Klein & Kihlstrom, 1994; McCaul & Maki, 1984). Within the emotional memory literature, it has been suggested that rapid, pre-attentive processing of emotional stimuli culminates in increased use of controlled resources and that consequent increases in post-stimulus elaboration contribute to enhanced memory for emotional stimuli (Christianson, 1992). According to the elaborative processing hypothesis, when encoding resources are limited, the automaticity of processing the emotion benefits memory formation. On the other hand, when plenty of cognitive or encoding resources are available, then the automatic benefits of emotion accumulate and benefits from deep, elaborative encoding are seen, which may be generalizable to emotional as well as neutral material.

Findings from behavioural studies show that emotional memory is enhanced when words are encoded under a shallow versus deep processing condition (Jay, Caldwell-Harris, & King, 2008; Reber, Perrig, Flammer, & Walther, 1994) thus lending support to an elaborative processing hypothesis. These results indicate that shallow processing amplifies the difference between emotional and neutral words, likely due to automatic arousal mechanisms that distinguish emotional from neutral stimuli, whereas relative benefits in elaborative processing occur for neutral stimuli in the deep condition. These findings echo behavioral evidence that dividing attention during encoding impacts memory less for arousing stimuli than for neutral stimuli (Kensinger, 2004; Kensinger & Corkin, 2004; Kern et al., 2005).

From the behavioral literature, it is clear that emotional memory is enhanced through elaboration. From imaging studies, we know that this enhancement occurs even in the least elaborative condition that is shallow processing of stimuli (M Ritchey, LaBar, & Cabeza, 2011). However, such evidence from behavioral and imaging data does not tell the whole story. What still remains unknown is which one of the levels of elaboration (shallow, semantic, self-referential) is superior to the other in mediating the relationship between emotion and memory. Answering this question could help develop a model of emotional memory enhancement. Part of the present project is an attempt to elucidate the role of elaboration on emotional stimuli using low arousal words as stimuli.

1.4.4 Anticipation and EEM

A lesser studied mechanism is described by the emotional anticipation model, which attempts to account for the SME with a focus on the pre-encoding or pre-stimulus brain activity and its role in memory formation (Galli, Wolpe, & Otten, 2011). The evidence comes from an ERP study (Galli, Bauch, & Gruber, 2011) showing that merely the anticipation of an emotional event in the pre-stimulus phase resulted in a subsequent memory or Dm effect. SME/Dm effect is the difference between the neutral activity of remembered and forgotten item for an emotionally negative event. Pre-stimulus Dm effect was observed in female participants in female participants only in ERP (Galli, Wolpe, et al.,

2011) as well as in fMRI (Mackiewicz, Sarinopoulos, Cleven, & Nitschke, 2006b) studies. What is known so far regarding the anticipation of emotional event/stimuli is that emotional anticipation results in a memory-related ERP difference before the occurrence of an actual event. However, ERP study emphasized that arousal did not account for the SME observed from the anticipation of emotional stimuli (Galli et al., 2011). Furthermore, this explanation contrasted with findings from the fMRI study where anticipatory SME was attributed to the anticipation of high-arousal negative stimuli (Mackiewicz et al., 2006).

As previously mentioned, the literature on cortical measures of anticipation in general and its relation to emotional memory in specific is scarce. An ERP study investigated the modulatory role of anticipation in emotional memory formation (Galli et al. 2011). The findings of this study attributed the difference between remembered and forgotten waveforms (pre-stimulus Dm effect) to the preparatory process at work during the pre-stimulus phase. However, findings of this study have not been replicated by independent laboratory investigations. Moreover, there are considerable design and methodological limitations associated with this study, such as a lack of control group and the use of pictorial stimuli as cues. These limitations will be discussed in detail in the relevant chapters. The starting point for the present study is the assumption that SME-related activity observed at the pre-stimulus phase might not be a reliable indicator of memory encoding. Rather, it may just be the result of random fluctuations in attention. The assumption of random fluctuation is based on the findings of a study where the researcher found a Dm-effect at the pre-stimulus phase when the participants were unaware of the valence of the upcoming picture (Yick, Buratto, & Schaefer, 2015). The mechanism behind Ps-Dm effect is the preparation to deal with the upcoming emotional information (Galli et al., 2011; Galli, Griffiths, et al., 2012). Yick et al. (2012) found a Ps-Dm effect without preparatory informative cues which give rise to the idea that the neural difference between remembered and forgotten might reflect just random fluctuation in attention while participants are waiting for the stimulus to appear. This study was not basically designed to investigate Ps-Dm effect. However, the exploratory analysis revealed a number of questions about the reliability of the Ps-Dm effect.

There are a number of general themes that are intriguing; for instance, the behavioural outcome of anticipation is largely understudied. The studies so far have focused exclusively on differences in neural activity, and not on the behavioural aspect. Is there plausibility of getting a Ps-Dm effect without preparation as obtained by the finding of study (Yick et al., 2015)? Does the presence of the cue really matter, or can we get this effect in the absence of cues too? Do the cues need to be pictorial to get the Ps-Dm effect or it can be obtained when non-pictorial cues (such as letter: X, O, Z) are used to represent the type of upcoming emotional and neutral picture? What role does the valence and arousal of the pictures (to be anticipated) play in Ps-Dm effect? Thus far, studies on the anticipation-related Dm effects have given different explanations: one attributed the differences to the arousal level of stimuli (Mackiewicz et al., 2006) while another reported that they were modulated by valence instead of arousal (Galli et al., 2011). Additionally, there is a controversy between the explanations of both these studies in that the anticipatory processes at pre- and post-stimulus phases are dissociable and independent.

Moreover, it is unclear whether the arousal and valence dimensions can be dissociated in the topographical characteristics of anticipation. Although there is some evidence that valence-related differences tend to be larger at anterior electrode sites (Galli, Wolpe, et al., 2011), such topographical dissociation has not been clearly demonstrated. A systematic understanding of how these factors would contribute to the Ps-Dm effect is still lacking. Considering the lack of unified methodology and inconsistent findings on this issue, the primary aim of this thesis is to provide empirical and theoretical evidence for the anticipation Rationale behind the experimental framework

Elaboration and anticipation are both under-explored mediators of emotion on memory, despite the fact that they are both key potential mediators of EEM. While recent research suggests that elaboration might play a role in EEM, perhaps what is important is not elaboration itself, but the attentional processes that it triggers. In this sense, it might be argued that "elaboration" paradigms tend to trigger anticipation/preparatory processes. The primary concern of all the current experiments is to provide a conceptual, theoretical framework for EEM based on the manipulation of the level of processing and anticipatory cues. In this thesis, two sets of projects will be discussed, which used behavioral measures and ERP recordings. The second project was initiated after the first project failed to produce encouraging results.

Three behavioural studies were conducted to explore the role of elaborative processing in enhancing emotional memory. Although the results were not promising to warrant follow-up ERP studies, the next studies focused on analyzing the behavioral results with respect to anticipation and emotional memory.

1.5 Behavioural Procedures and EEM

1.5.1 Recall memory

A typical EEM paradigm involves two phases: encoding and retrieval. Participants encode emotional and neutral stimuli in the first phase, then after a period of delay or immediately after the exposure of emotional and neutral stimuli, the memory of the participants are tested. Memory is tested either by free recall or recognition method depending on experimental design and the hypothesis under investigation. Using free recall method participants first encode a series of verbal or visual stimuli and then they are asked to recall as many items as they recall and write on a piece of paper. They are requested to provide all possible detail of the recalled memory. In most of the studies on EEM same procedure has been adopted (Pottage & Schaefer, 2012; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008; Talmi, Luk, McGarry, & Moscovitch, 2007; Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014). More specifically the studies. In the current project, recall method was used as a test of memory performance for the hypothesis related to the role of elaboration or level of processing in enhancing emotional memory. It was done because a number of studies have found recall more effective in verbal stimuli.

1.5.2 Recognition memory

Using recognition memory, participants are presented with the same set of stimuli, which they were presented with at encoding phase, however, with an addition of a new set of stimuli. Participants had to classify stimuli into ‘Old’ and ‘New’ depending on what they recognized. Recognition memory test provides more cues to participants which aid in retrieval compared to free recall. Recognition memory is extensively used method (Dolcos et al., 2004; Ochsner, 2000; A Schaefer et al., 2011; Sharot & Phelps, 2004). Since this method results in more hits rates, therefore, two additional tasks are used to rule out any guess in studies to get more confidence, depth and the source of recognized memory. Thus, confidence ratings and Remember/Know judgment tasks are employed. R-judgments, also known as recollection and K-judgments also named as familiarity are assumed as sub-components of recognition memory according to Dual process model of memory. By definition, recollection/R-Judgment is the retrieval of an emotional/non-emotional event that is accompanied by detailed and associated information of the event such as time and location. In contrast, familiarity/K-judgment is the feeling that an event experienced before. However, its details are missing. Dual process theory assumes these two memory components are distinct as they recruit different brain regions (Bowles et al., 2007, 2010; Squire, Wixted, & Clark, 2007). There is controversy on this issues as Single process theory criticizes familiarity and recollection are two different subcategories of memory. Rather it posits that recognition ranges from weak to stronger memory on a single continuum and engage same brain regions (Curran, DeBuse, Woroch, & Hirshman, 2006; Mandler, 2008; Rutishauser, Schuman, & Mamelak, 2008). Despite this controversy, the majority of studies in neuroscience heavily rely on Dual-process model. In the current investigation, Remember/know judgment task has been used because studies on Ps-Dm effect have found a greater influence of emotion on the accuracy of Remember judgments than Know judgments and overall recognition memory accuracy. Recognition memory was tested with a 24 hours' delay where participants were presented with all the pictures they saw in the encoding phase intermixed with new pictures. In the current project, they were also asked to provide confidence rating for their responses.

1.6 Gender difference and Pre-stimulus activity

For all studies, only female participants were recruited in order to reduce gender-related heterogeneity in the sample based on previous evidence for a gender difference in response to affective stimuli (Cahill et al., 2001; Greenberg, Carlson, Rubin, Cha, & Mujica-Parodi, 2014; Hamann, Herman, Nolan, & Wallen, 2004; Killgore & Yurgelun-Todd, 2001; Stevens & Hamann, 2012). One potential explanation for the pre-stimulus Dm/SMEs in the female but not the male sample might pertain to their heightened sensitivity or responsiveness to emotional stimuli (Galli et al., 2011). A limitation of Galli's study is that it lacks analysis regarding any ERP index for females' greater response to emotional stimuli. Moreover, the study did not include a control or baseline condition for comparisons, such as a non-informative or no-cue condition. It is, therefore, speculative to attribute the Dm/SMEs to excessive female sensitivity to emotional stimuli. Significant pre-stimulus differences in activity have also been found under the non-informative cue condition (Mossbridge et al., 2012). In an ERP study (without memory as a factor), Jin et al. (2013) found an enlarged P2 component that likely reflects the greater allocation of attentional resources by females in order to detect unexpected stimuli as compared to predictable stimuli. Additionally, this sensitivity towards the unanticipated condition was observable equally for neutral as well as emotional stimuli. In both these studies, all the female participants were controlled for their anxiety levels. Therefore, the reported results need not be attributed to a vigilance-related attention bias.

It seems that foreknowledge or the lack of information regarding the upcoming emotional and non-emotional pictures might have the same impact on the processing and encoding of these stimuli. The possibility remains that under situations where there is a lack of information about the impending event, the resolution is made by finding a relationship between environmental cues and the subsequent event (Alloy & Tabachnik, 1984).

1.7 Selection of Event-related potential (ERP)

A number of imaging techniques have been used to study EEM, such as functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET) and Magnetoencephalogram (MEG). However, in the present investigation, Event-related Potential (ERP) was chosen over other techniques because of certain important advantages, like its high temporal resolution, and the scope of information it provides. For example, although, fMRI investigations have shown that encoding-related neural activity can be modulated by emotion, suggesting that a number of structures (amygdala, hippocampus and prefrontal cortex) are involved in the formation of emotional memories (Erk, Martin, & Walter, 2005; Vuilleumier et al., 2004), almost no information on the time course of the modulation is provided. Whereas fMRI can accurately identify those brain regions actively involved in encoding emotional stimuli, ERP measurements allow the identification of the precise point in time at which this activity started, how long it was sustained, and when it ended.

A handful of electrophysiological studies (Dolcos & Cabeza, 2002; Kiefer, Schuch, Schenck, & Fiedler, 2007; Padovani, Koenig, Brandeis, & Perrig, 2011) have examined the modulatory role of emotion using event-related potentials (ERP), which allows a more precise examination of the temporal dynamics of neural activity compared to fMRI. One of these studies (Dolcos & Cabeza, 2002) found emotional effects on encoding-related activity in a 400-600 ms window, and others (Kiefer et al., 2007; Palomba, Angrilli, & Mini, 1997) found similar effects in a 250-500 ms window. However, these ERP studies did not address the EEM phenomenon; they merely examined how emotion modulates encoding-related activity, predicting whether the information will be retrieved rather than forgotten using a subsequent memory test. The current investigation is motivated by the fact that the ERP technique provides an excellent opportunity to answer such questions. The Event-Related Potential (ERP) is a particularly useful tool for investigating early anticipatory processes as the ERP can provide a direct cortical measure of anticipatory processes on the scale of milliseconds to seconds. Distinct aspects of anticipatory processing have been linked to different ERPs, and disturbances in these ERPs are seen in several clinical populations.

However, it should be noted that there are certain important limitations to ERP measurements. Compared to fMRI, ERP is less precise with respect to spatial resolution. However, with prior knowledge about brain regions involved in EEM (obtained using fMRI), ERP can make a significant contribution to an enriched model that accounts for temporal aspects of the phenomenon. Using ERP in the current project would allow the time-course of brain activity to be tracked during emotional anticipation/elaborative strategies on-line on a time scale of milliseconds. ERP is, therefore, a technique well-suited for studying covert memory encoding processes related to emotional anticipation, which cannot be observed overtly using behavior measures.

1.8 Significance of the issues

Investigation and clarification of cognitive processes underlying elaboration and anticipation are important for understanding both the behavioural and the neural mechanisms involved in emotion-memory interactions. This has ramifications not only for healthy functioning humans but will also help us understand the mechanism behind flashbulb memories, which are a hallmark of Post-Traumatic Stress Disorder (PTSD) and consequent depression and anxiety. The primary aim of this project is to investigate aspects of a significant unanswered question: how do emotions enhance memory? In order to provide a comprehensive understanding of the emotional memory interaction, the influence of elaborative processing on EEM was first examined and then on the role of anticipation in EEM and explore the effect of the valence and the arousal dimensions of stimuli on anticipation.

1.9 Thesis Objective

Following objectives will be ascertained in this thesis. Each objective has been addressed in the separate chapter.

(i) Does the level of processing (elaboration) enhance emotional memory? If yes, then which level of processing strongly mediates the relationship between emotion and memory (Chapter 3).

(ii) Does the anticipation of emotional stimuli benefit memory at the behavioural level? (Chapter 4).

(iii) Does the presence and absence of cues matter for a reliable Ps-Dm effect at neural level? (Chapter 5).

(iv) What role does valence play in Ps-Dm effect under Informative and Non-informative cues conditions? (Chapter 6).

(v) What role does emotional arousal play in Ps-Dm effect under Informative and Non-Informative cue conditions? (Chapter 7)

Chapter 2: General Electroencephalography Method

2.1 Overview

The fundamental goal of cognitive neuroscience is to explore neural processes underlying complex high-order cognitive processes such as emotion and memory. Many methodologies have been employed in this quest, however in contrast to imaging techniques, for example, which have good spatial, but poor temporal resolution, the methodology employed forthwith relies on electroencephalography (EEG).

EEG is, a non-invasive technique, which records electrophysiological correlates of cognition; event-related potentials (ERP; stimulus-related time sensitive epochs of EEG) allow specific windows of insight with respect to neural activity during such processes

The fundamental aim of the ERP experiments to follow is to uncover the electrophysiological correlates of emotional memory during the anticipatory or pre-stimulus phase of the experiment. Given that ERPs provide simultaneous multi-dimensional online measures of polarity (negative and positive potentials), amplitude, latency and scalp distribution of activity, this is an ideal tool with which to investigate such issues.

This chapter provides a detailed account of ERP methodology, while the description of the participants, design, stimuli and procedure will be described in individual chapters. In relation to the theme of this project, a brief background of the ERP technique, its key characteristics and features, hardware and software used, steps involved in pre-processing and ERP data reduction have been discussed in detail.

2.2 EEG/ERP background

Electroencephalography (EEG) is the measurement of electrical activity in the brain. It is measured with millisecond precision by electrodes placed on the surface of the scalp. The roots of EEG recording can be traced back to Richard Caton (1842-1926) and later Adolf Beck (1891) demonstrated electrical oscillations on the surface of a primate cortex. However, in the first ever published report on EEG, Hans Berger (1929) demonstrated that electrical activity elicited on the scalp was analogous to the activity recorded from the cortical surface (for review see; Davidson et al., 2000). Ever since, there has been a great interest in identifying relationships between EEG recordings and cognitive processes (see review: Fabiani, Gratton and Coles, 2000). Consequently, the modern era of EEG/ERP research started with the discovery and publication of the first cognitive ERP components called Contingent Negative Variation (CNV) by Walter Grey and the P3 component by Sutton et al. (1965). In the next few years, development of more sophisticated computers, tools and technology gave rise to a tremendous amount of research on EEG/ERP (Collura, 1993). Currently, EEG/ERP is one of the most widely used methods in cognitive neuroscience for the investigation of the electrophysiological basis of different sensory, perceptual and cognitive activity associated with processing information (Handy, 2005).

2.3 Spontaneous EEG versus ERP

EEG records spontaneous electrical brain activity in the form of electrical brain waves. Event-related potentials (ERPs) are embedded in raw EEG and need to be extracted from the raw data. ERPs consist of a sequence of positive and negative voltage fluctuations much smaller in amplitude (few microvolts, i.e., 1-20 μV)). The ERP signal is time-locked to the repeated occurrence (e.g. 100 or more trials) of a particular event. Spontaneous EEG is the sum of ERP signals and the noise that is unwanted electrical activity recorded along with EEG activity. Different methods are used to reduce noise from the data at the time of recording as well during pre-processing such as filtering and artefact rejecting (discussed in detail section: 2.6.1). Event-related signals are averaged across conditions and subjects after reducing noise. For an illustration of how EEG and ERP waves form look like see figure 2.1 below.

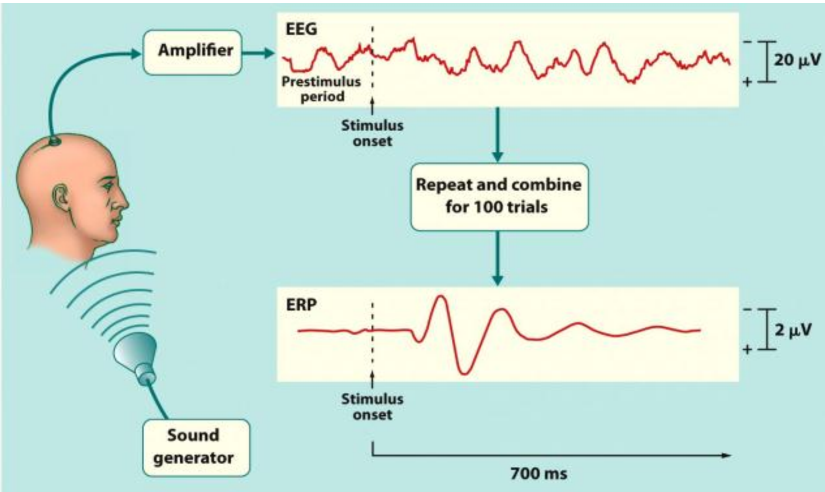


Figure 2.1: Spontaneous EEG to ERP

EEG records data corresponding to the triggers which are time-locked to the stimulus. The raw EEG data are averaged off-line to get an ERP waveform for the event. Then, a single ERP waveform is drawn by superimposing all the individual ERP waveforms. That gives the average of all the participants which is used in the statistical analysis. Reprinted from “Cognitive Neuroscience: The biology of the Mind,” Third Edition, by M.S. Gazzangia, R. B. Ivry and G.R. Mangun, p.149.Copyright© 2009.1002, 1998. Used by permission of w.w.Norton &Company, Inc.

The ERP technique has advantages over another EEG technique called event related oscillation (EROs). In contrast to ERPs, EROs are characterized by slow but high amplitude (approx. 50 µV) oscillations. These oscillations are assumed to result from the rhythmic changes in the activity states of large groups of neurons. EROs are analysed and reported in frequency bands and reflect the brain's global electrical activity (see Figure 2.2). Some specific type of EROs appears in Tremor, Parkinson's disease and Epilepsy. ERPs are considered a more powerful approach as compared to EROs because ERPs focus on how brain electrical activity is modulated in response to a specific cognitive task.

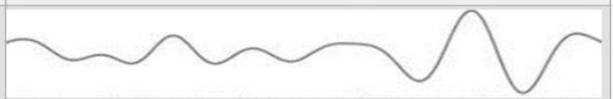
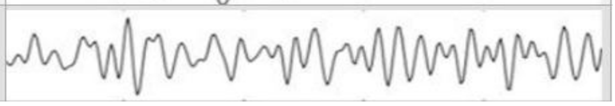
Frequency Band Name	Frequency Bandwidth	Mental States	Filtered Bandwidth
Raw EEG	0- 45 Hz	Awake	
Delta	0.5 - 3.5 Hz	Deep Sleep	
Theta	4 - 7.5 Hz	Drowsy	
Alpha	8 – 12 Hz	Relaxed	
Beta	13 – 35 Hz	Engaged	

Figure 2.2: Spontaneous EEG and Frequency bands

Reprinted from "Introduction to Quantitative EEG and Neurofeedback: Advanced Theory and Applications. 2nd Edition, by Budzynski, H., Budzynski, T., Evans, J.Copyright© 2009. Used by permission of Elsevier Inc.

2.4 Features and characteristics of ERP

2.4.1 Signal-to-noise ratio

Signal-to-noise ratio (SNR) is a measure of signal strength relative to background noise. Signal reflects the measured voltage coming from the brain while noise reflects voltage coming from external (electricity power supply noise) or internal sources (blinks, eye movements, skin potential and muscle tension) (Luck, 2014). A higher SNR shows a better-quality signal with least amount of noise. To get a clean ERP signal, researchers try to increase the signal-to-noise ratio using procedures such as filtering and averaging. Signal remains unaffected when a large number of trials are averaged together (Willinek et al., 2007). The SNR is mathematically represented as (1 / $\sqrt{N}$) $\times$ R and measured in decibels (dB). In this equation, N is the number of trials and R is the amount of noise in a single trial. Let's take an example, say amplitude of P3 component is 20 µV and EEG noise is 50 µV on a single trial, then S/N ratio on a single trial will be 20:50 or 0.4. If two trials are averaged, then the SNR ratio will increase by a factor of 1.4 (because $\sqrt{2}$= 1.4). So to increase the S/N ratio from 0.4 to 10, it will require 625 trials ($\sqrt{625}$ =25). Thus, SNR increases as a function of the square root of the number of trials. It means that to achieve a reasonable S/N ratio in ERP experiments we require a large number of trials (Handy, 2005; Luck, 2005).

2.4.2 Components

An ERP signal/component is typically described in terms of its polarity, timing and scalp distribution (Friedman & Johnson, 2000). However, there has been some controversy among researchers in defining ERP components. Luck (2005) defines an ERP component as a "scalp recorded neural activity that is generated in a given neuroanatomical module when a specific computational operation is performed" (p.66). An alternative and more operational definition were provided by Manny Donchin; "an ERP component is a source of controlled, observable variability" (Donchin et al., 1978, p. 354). However, this definition has two flaws: first, it discounts the key idea that a specific neuroanatomical module generates an ERP component. Second, controlled experimental manipulation ignores the role of spontaneous and correlational variation in an ERP component. Taking this criticism into consideration, the most up-to-date, precise, and operational definition thus far states, "An ERP component is a set of voltage changes that are consistent with a single neural generator site and that systematically varies in amplitude across conditions, time, individual, and so forth" (Luck, 2014, page no.68).

2.4.3 Nomenclature

ERP components are labelled with their polarity, latency, amplitude and scalp topography. Polarity refers to the positive or negative deflection in the waveform while latency refers to a time point at which the polarity occurs. Most of the ERP components are denoted by polarity initials (P/N) followed by a number indicating either order or latency in milliseconds. For instance, the first positive (P) peak in the waveform after stimulus onset is referred to as P1, the second as P2 the third P3, and the first negative peak is referred to as N1, the second as N2, the third as N3 and so on. Latency numbers indicate the occurrence of polarity at or around 100ms, 200ms or 300ms (see figure 2.3 for an illustration). However, the latency numbers attached to a component are only loosely related to its timing. For instance, a P300 component has been observed from anywhere between 300-800 ms post stimulus onset (Stren et al., 2001). A few other ERP components are referred to in a task related manner such as Contingent Negative Variation (CNV), Stimulus-Preceding Negativity (SPN) and difference due to memory (Dm).

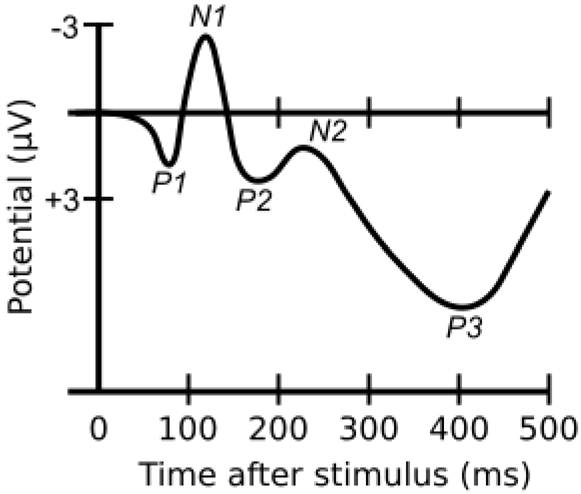


Figure 2.3: ERP nomenclature

ERP waveforms show a series of negative and positive voltage deflection and are linked to a set of underlying components. ERP components are labelled depending on the order of occurrence and polarity of the components. For instance, the first peak in the waveform is a negative-going peak, occurs about 100 milliseconds after a stimulus onset and called the N100 (indicating its latency is 100 ms after the stimulus and that it is negative) or N1 (indicating that it is the first peak and is negative); it is often followed by a positive peak, usually called the P200 or P2. Some components are labelled according to the polarity only, for instance, P300 component may exhibit a peak anywhere between 250ms – 700ms. Reprinted from "*An introduction to the Event-Related Potentials Technique*," Second Edition, by S. J. Luck, p.149 copyright © 2014, 2005 by S. J. Luck. Used by permission of MIT Press.

ERP waveforms are usually shown as plotted negative upward on the ordinate (see figure 2.3 for an example) because early neurophysiologists recorded brain action potentials as upward spikes which became conventional (Luck, 2014). Today some laboratories plot positive upwards and some use the negative up-convention. In this thesis, however, the standard scientific approach of plotting positive values upward has been adopted.

2.4.4 Identifying a component

Some commonly identified ERP components such as P1, N1, P2, N2 are considered as 'sensory' or 'exogenous' components as they largely depend on the physical properties of the stimulus (Sur and Sinha, 2009). For instance, ERPs generated in later parts of the waveform reflect the manner in which the subject evaluates the stimulus while processing information. The components P300, P3a, P3b, and N400, are considered as 'cognitive' or 'endogenous' ERPs (Donchin, Ritter and McCallum, 1978). The Dm effect is also considered an endogenous ERP component, which reflects successful encoding by showing the ERP difference between the remembered and forgotten ERP waveforms. Similarly, early posterior negativity (EPN) and the late positive potential (LPP) components are assumed to reflect emotional processing of error-related negativity (ERNcomponent is linked to incorrect behavioural responses (Luck, 2014). Furthermore, Contingent Negative Variation (CNV) and Stimulus Preceding Negativity (SPN) components have been identified as the ERP components involved in motor preparation and anticipation of emotional stimuli respectively (Luck, 2014). However, identification and measurement of several components depends on the experimental task and are subject to variation depending on the investigation and the type of stimuli.

In ERP methodology, defining and extracting ERP components is a central issue. A conventional approach towards identification of the ERP components relies on the knowledge of existing ERP components with similar latencies and scalp distributions. Further, an understanding of the type of cognitive processing involved in the task is needed. However, this ERP approach is not without its shortcomings. For example, there is significant variability in latency of components and scalp distribution across studies and across participant characteristics. Therefore, a trained ERP researcher might be more adept at identifying the component in an ERP waveform considering all relevant variables of interest.

The current project focuses heavily on memory- and emotion-related components at the pre-stimulus and post-stimulus phase, namely the Dm effect. Dm effect is the difference between the neural activity of remembered Versus forgotten items manifested after the picture display. Additionally, it has recently been found that Dm effect can be elicited prior to picture display in response to anticipation of emotionally negative stimuli. However, the Dm effect parameters in response to anticipation are not well identified and documented as compared to Dm effects in response to realistic pictures themselves. In ERP studies first EEG waveforms are sorted into remembered or forgotten categories based on the performance of memory test. Then, all the remembered and forgotten trials are averaged separately. Finally, forgotten waveforms are subtracted from the remembered ones, and the resultant difference is named as the Dm effect or subsequent memory effect. In most cases, the Dm effect is seen over centroparietal electrode sites in the 400-800ms time interval with positive deflections. In a few instances, left anterior activity has also been observed. Scalp distribution of the Dm effect relies on whether the stimuli are pictures or words, and also the instructions were given to the participants. While drawing inferences, one should take into consideration that Dm is not a single component, but rather reflects many different processes that can influence whether a stimulus is later remembered (Luck, 2014).

Two other approaches that help to identify and define ERP components are principal component analysis (PCA) and independent component analysis (ICA). Both approaches are based on correlational analysis of ERP data (Handy, 2005). PCA is essentially a factor analysis technique that attempts to identify covariance in waveforms to extract components (Pourtois, Delplanque, Michel, & Vuilleumier, 2008; Skrandies, 1989). In contrast, ICA uses linear and non-linear associations to identify components. It should be noted that there are some major drawbacks of correlation-based measures. For instance, two distinct processes may be captured as one component, or a single component may be parsed into separate components, which might vary in latency across conditions (Luck, 2014).

2.4.5 Inferences and ERP data

Once the ERP components are identified, the next step is to look for reliable differences between conditions for the identified ERP components. Several inferences can be drawn from ERP data. First, ERP waveforms from two conditions that may have significantly different effects on the ERP can be compared. The assumption behind this comparison is that a single ERP reflects neural activity related to a specific cognitive mechanism. A statistically significant difference between the ERPs of both conditions signifies that cognitive processes related to the two conditions differ in some way (Otten & Rugg, 2001). Second, by comparing the timing in which those differences are manifested, we may infer when the differentiated effect occurred and for how long it lasted. Third, the spatial differences between the conditions can tell us, for example, if ERP effects stem from non-equivalent cognitive processes. In such a case, the ERP effects will be widely distributed over the scalp (Luck & Kappenman, 2012). Generally, these inferences can be drawn using a standard statistical test like the Analysis of variance (ANOVA).

2.5 ERP: Hardware and software

2.5.1 Stimulus display

The E-Prime 2.0 programming platform software (Psychology Software Tools, Inc., Pittsburgh, PA) was used to display the stimuli in Windows 7 using a Dell Latitude 6500 computer, and to send ERP triggers. The display was presented on a 40 cm × 30 cm Samsung SyncMaster computer screen (TCO’03 Displays, MagicBright) with a resolution of 1,024 × 768 pixels. Screen refresh rate was set to 70 Hz to control for flicker. In EEG/ERP studies, stimuli are presented with millisecond precision. It is essential to monitor the accuracy and precision of stimulus presentation, synchronization, and response time to avoid timing errors. In the current project, the accuracy of synchronization between stimulus onset and trigger received by the EEG system were verified using the BlackBox Toolkit (BlackBox Toolkit Ltd., York, UK).

2.5.2 Data recording and acquisition

Electroencephalographic activity was recorded using an Advanced Neuro Technology (A.N.T.) Waveguard EEG cap with 64-shielded Ag/AgCl sintered electrodes (A.N.T. Software B.V., Enschede, The Netherlands; Fig. 2A). This 64 channel cap uses 10/10 electrode system which is an extension of the most widely used standardized electrode placement 10/20 system (Jasper, 1959) developed for 32 channels. A further advancement of the 10-20 system is called the 10/5 system for up to 128 channels (Chatrian et al. 1985). All systems describe the anteriority (prefrontal, frontal, central, occipital) of scalp electrodes. These systems are based on the relationship between the anteriority of an electrode and its underlying area of cerebral cortex. The distance is given in percentages range between Nasion-Inion and fixed points. These points are marked as the Frontal pole (Fp), Central (C), Parietal (P), occipital (O), and Temporal (T). Electrodes over the midline are shown with a subscript "z", standing for zero. The even numbers, to the right and odd numbers over the left hemisphere are used as a subscript for points (see figure 2.4).

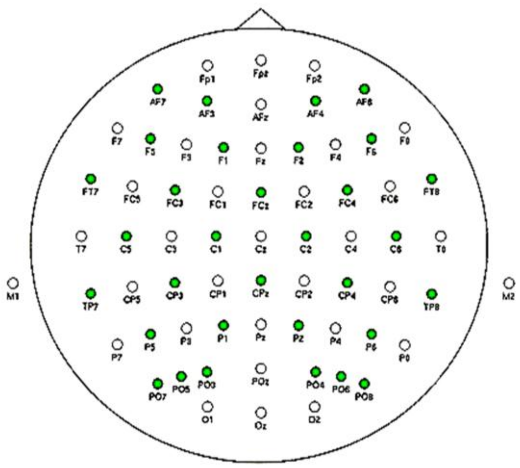


Figure 2.4: The 64-channel cap layout with 10/10 system

A standardized electrode placement system is used when dealing with multiple electrodes. The standardized system is referred to as International 10-20 or 10-10 system. It allows for better collaboration among researchers. Reprinted from ANT Neuro inspiring technology website with permission from ANT Neuro wave guard company.

2.5.3 Amplifiers and Impedance

Amplifier systems differ in their input impedance. An ASA lab amplifier system (64 refs, 4 bit, 4aux) was used during the current thesis which comes with full-band EEG DC amplifiers with maximum 10,000 Hz sampling rates (see figure 2.5 for illustration)High impedance means higher resistance to current flow. High impedance is a source of noise and therefore during data acquisition, the electrode to scalp impedance threshold is set at each electrode site. The lower the impedance of the electrode, the higher the amplitude of the EEG signal. In the current experiments impedance thresholds were kept below 10 kΩ and sampling rate was 512 Hz.

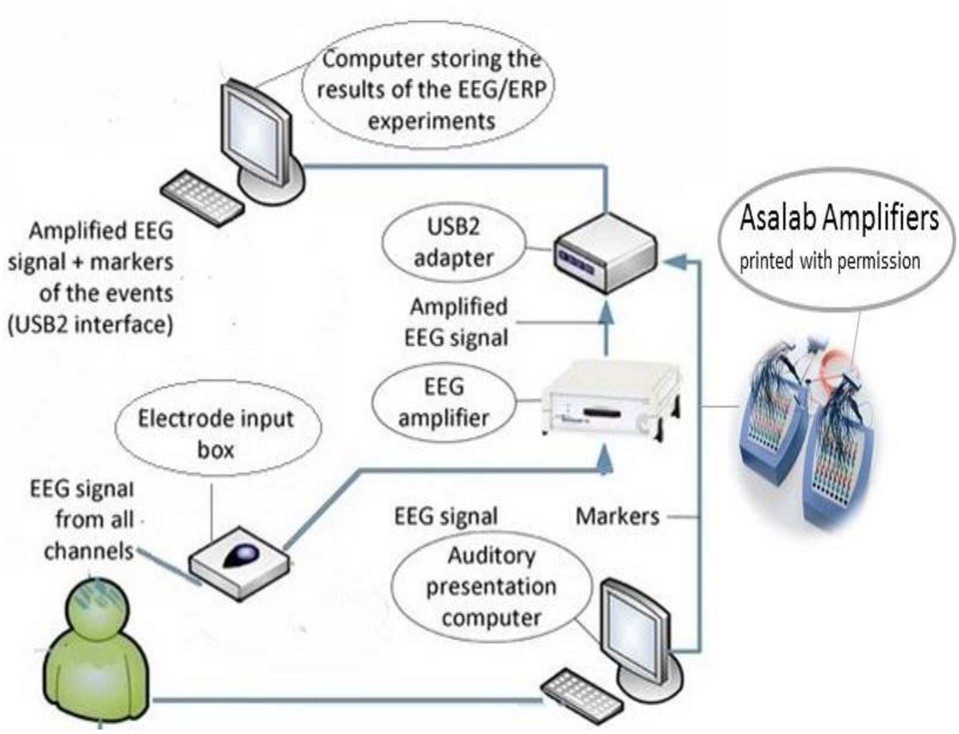


Figure 2.5: Experimental set-up for a typical ERP experiment

An illustration of '*ASA lab amplifiers'* used in the current experiment. Image reprinted from ANT Neuro inspiring technology website with permission from ANT Neuro wave-guard company.

2.5.4 EEG montage and reference electrode

An EEG/ERP amplifier measures the voltage difference between an active and a reference electrode over a period of time (Luck, 2014). However, it is not a direct measure of the voltage difference because it may host the electrical activity built up in the participants. To tackle this issue, differential amplifiers are used to enhance the difference between active and reference electrodes by subtracting the unwanted signal common to these two electrodes. ERP activity can be monitored with either a bipolar or a referential montage. A montage refers to a combination of multiple derivations or recording combinations. The two types of montages used are bipolar and referential. A bipolar montage has two electrodes per channel, so there is a reference electrode for each channel. A referential montage has one common reference electrode for all the channels. It includes a common average reference, a Cz reference, and an earlobe or mastoid as a reference. In the current series of ERP experiments, a referential montage, i.e., vertex (Cz), was used to record data online.

2.6 Data analysis

2.6.1 ERP: Pre-processing of data

Once EEG data is recorded, the next step is pre-processing. As mentioned earlier, ERPs are embedded in and extracted from raw EEG traces. Recorded EEG is the summation of electrical activity generated in response to brain activity from a specific cognitive task as well as from other unwanted sources. In this case, brain related voltage is referred to as the signal, while the voltage from all other sources is considered to be noise.

Noise contaminates ERP data and interferes with the ability to make specific inferences from the data. ERP activity is time locked, and the waveforms are identical. In contrast, noise fluctuates in a random fashion in each single recorded trial. The purpose of pre-processing is to improve the quality of the signal by increasing the signal-to-noise ratio through filtering, segmenting, artefact rejection, averaging and re-referencing. Data pre-processing involves multiple steps summarized in the sections below.

2.6.2 Filtering

Filters can be used to improve the signal-to-noise ratio. Filtering involves removing a portion of the recorded signal that is considered to be noise (Handy, 2005). One example is the notch filter that removes electricity or power line noise by filtering frequencies at 50 or 60 Hz. Filtering can be done by means of both analogue and digital filters. Analogue filtering relies largely on hardware components and can be included while EEG data is being recorded online. In contrast, digital filtering is often done after recording EEG data. Digital filtering can be used more flexibly without distorting the original data and the phase of frequency in the waveforms (Picton et al., 2000). High and low pass filters are also commonly used to specify a range of high and low frequencies for conditions. High pass filters are often used to reduce skin potentials by passing high frequencies and attenuating low frequencies. Low pass filters deliver low frequencies by filtering out high frequencies. This controls the noise arising from muscle activity or other electronic devices. Because online filters distort data and lead to loss of information, only offline filtering was used in the current experiments. Data was filtered offline for the pre-stimulus phase (0.03-20 Hz), and post-stimulus phase (0.03-30 Hz), and corrected for eye movements (Berg & Scherg, 1994).

2.6.3 Artefact identification and correction

Artefacts are signals which are non-cerebral in nature and are considered to be noise. There are two categories of artefacts; 1) those arising from participants, such as eye blinks, eye movement, muscle activity, sweating, pulse and cardiogenic electrical activity, and 2) artefacts caused by technical issues, which include AC power line noise, high impedances, detachment of electrodes during recording, use of excessive gel in electrodes, broken wires, and faulty connections.

Eye blink amplitudes, which range from 50 and 100 μV, are easy to ascertain, as they result in deflections of opposite polarity for electrodes above and below the eye. Online and offline strategies were used to reduce the occurrence of eye blinks and movement artefacts for the data presented here. While recording ERP data, participants were explicitly asked to try to minimise the amount of eye blinking and body movements. Eye blink artefacts were corrected off-line using Multiple Source Eye Correction method. This method employs a model of brain activity through multiple current dipoles (Scherge and Picton, 1991). It first takes the sum of eye movement and blinks in the data and compares it with brain activity; then it corrects for overlaps in cerebral activity (Berg & Scherg, 1994). An automatic eye-blink correction method was used, made available by the BESA software.

Artefacts caused by muscle movement were controlled by providing comfortable seating arrangements. Offline muscle movement artefacts were identified and corrected in those time segments where the difference between the maximum and minimum voltage was greater than 120 μV and where the maximum difference between two adjacent voltage points exceeds 75 μV. This correction was also done automatically in the BESA software.

Some EEG channels do not provide usable data for analysis due to the presence of technical artefacts — extremely high or low signals. As a result, some data is missed or becomes problematic with respect to EEG analysis because it might distort the rest of the recorded data and in the worst case, might cause rejection of whole data file. To avoid the risk of losing information, the number of bad channels should not exceed 5% of the total. Alternatively, it is possible to replace the EEG channel by interpolated data (Picton, et al. 2000). Interpolation is a mathematical technique for estimating missing data according to a linear or spline function; (Keil, 2014). The linear method estimates the value of an electrode from only a few nearby electrodes. In contrast, the spherical spline method (Perrin et al., 1989) takes signals from all electrodes over the scalp for a better estimate of missing data.

In all the ERP studies in this thesis, spherical spline interpolation was used to estimate the missing data, because it is less prone to noise from the surrounding electrodes.

2.6.4 Segmentation/epoch

EEG data can be recorded either in short epochs or over extended periods of time which later can be segmented to shorter time ranges offline. Epoch or segmenting is an important step in pre-processing. Each epoch comprises the time interval between the onset and offset of a single trial. It might be as short as 100ms or as long as 3000 to 9000 ms.

2.6.5 Baseline removal

As reported earlier, ERP data represent changes in voltage over a period of time, and, therefore, we need a baseline against which we can quantify this change. For this purpose, a baseline period is selected that is actually a portion of the time period before the onset of a trial (e. g. -200ms before the start of trial). ERP components are measured relative to the baseline. The baseline establishes a zero-voltage value from which the event related activity can be subtracted. A noisy baseline usually obscures experimental effects. Therefore, the mean value calculated during this baseline period is taken as an arbitrary zero and is subtracted from the rest of the epoch. It results in a measure of change for the ERP component with respect to this zero level. A 200ms baseline is generally used because it provides a more stable noise-free period of activity (Luck, 2014; Luck & Kappenman, 2012). In this thesis, a baseline of -200 ms to 0 ms relative to the cue stimulus and picture onset was chosen

2.6.6 Averaging

The last step in pre-processing is calculating the average ERP of many trials of a single subject across all conditions. Random noise is reduced by averaging, and the signal becomes more accurate reflecting the constant underlying ERP. Hence, as the trials increase in number, the noise decreases. The averaging process involves single subject average as well as a grand average of all the single subject averages. There are two popular methods for measuring ERP components: peak amplitude and mean amplitudes. Peak amplitude considers maximum values of the peak or the high-frequency waves as a measure of components. In contrast, mean amplitude takes the average amplitude of the component in the time window selected for the analysis.

In this thesis, the mean amplitude has been measured for the following reasons. First, mean amplitude is less prone to high-frequency noise as compared to peak amplitude (Luck, 2014). Second, mean amplitude from a single individual recording is similar to the mean extracted from grand average ERP waveforms across subjects (Luck, 2014).

2.6.7 Re-referencing

Data is re-referenced offline digitally, the purpose of which is to select a position that is close to the zero value. It helps to eliminate the effects of arbitrary recording reference channels on voltages. Re-referencing methods include an average reference method and link-mastoid and average mastoid. Average reference uses the average amplitude of all the electrodes as a reference. In contrast, average mastoid takes the average amplitude of the activity of the left and right mastoid as a reference. Linked-mastoid links the data to each mastoid separately. The data in this thesis was re-referenced to link-mastoid.

2.6.8 Statistical analysis

2.6.8.1 Repeated measures ANOVA

In the following experiments, the ERP module of Brain Electrical Sources Analysis (BESA) 5.1.8.10 software (MEGIS software GmbH, Gräfelfing, Germany) was used for ERP pre-processing and event-related averaging. Additional analysis of ERP data or ERP waveform plots and topographical graphs was performed using custom scripts are written in Matlab r2006b (The MathWorks, Natick, MA). Statistical analyses such as ANOVA and posthoc were carried out using the IBM Statistical Package for Social Sciences (SPSS-V:20).

Repeated measures ANOVA is the most commonly used statistical tool used for analysis of the ERP data. One consideration in using ANOVA is the sphericity assumption which is often violated. According to this assumption, the variance of all the levels of the comparison should be the same. In ERP research, this assumption is violated when data from the electrodes that are close together are more correlated than data from two distant electrodes. Further, random noise from the environment is stronger on frontal and central electrodes than to parietal clusters. Violation of the sphericity assumption may lead to a Type I error. Where appropriate, Greenhouse Geisser epsilon adjustment is used to avoid Type I error for ERP data analysis in the following experiments. This correction adjusts the degree of freedom downwards which results in higher p-values, in order to counteract the artificially low p-values resulting from the lack of sphericity (Keil et al., 2014; Luck, 2014; Luck & Kappenman, 2012).

One challenge in ERP studies is drawing inferences from the data from non-significant results. If we do not find a significant difference between two conditions, we cannot infer that there is no difference between the cognitive processes of the two conditions (Otten & Rugg, 2001). It might reflect the plausibility of functional differences between the two conditions, which are not captured by ERPs. Thus, the conclusions from null findings should be treated with caution in ERP studies (Rugg & Coles, 1996).

Across all the studies in this thesis, repeated measures ANOVA has been used to analyse data from specific time bins selected to capture components. The ANOVA variables include Anterior-Posterior (Anterior vs. parietal), hemispheric laterality (Right vs. Midline vs. Left), cue conditions (Anticipation vs. Non-Anticipation), valence (Negative vs. Neutral) and memory (Remembered vs. Forgotten). Significant main effects and interactions were further investigated using t-test corrected for multiple comparisons.

2.6.8.2 Electrode clusters

Data recorded at 64 individual electrodes were pooled together to form 6 electrode clusters spanning the frontal central and central-parietal scalp regions. The literature shows that the pre-stimulus Dm effect for pictures is observed over the frontocentral and centroparietal anteriorities, which varies as a function of the type of task and material used (Bennion, Ford, Murray, & Kensinger, 2013; Dolcos & Cabeza, 2002; Hirst et al., 2009; LaBar & Cabeza, 2006; Mackiewicz, Sarinopoulos, Cleven, Nitschke, & McGaugh, 2006). The clusters consist of the following electrodes: left anterior (F7, F5, F3, FT7, FC5, FC3) midline anterior (F1, Fz, F2, FC1, FCz, FC2) right anterior (F8, F6, F4, FT8, FC6, FC4) left posterior (P7,P5, P3, TP7, CP5, CP3) midline posterior (P1, P2, Pz, CP1, CP2, CPz) and right posterior (P8,P6, P4, TP8, CP6, CP4) based on the literature for the encoding-related post-stimulus SM effect analysis (see figure 2.6). Average amplitude from individual electrodes were pooled together to create clusters of electrodes across 6 scalp regions (Anterior and Posterior). This data reduction technique addresses a family-wise error in dense arrays of electrodes (Oken & Chiappa, 1986).

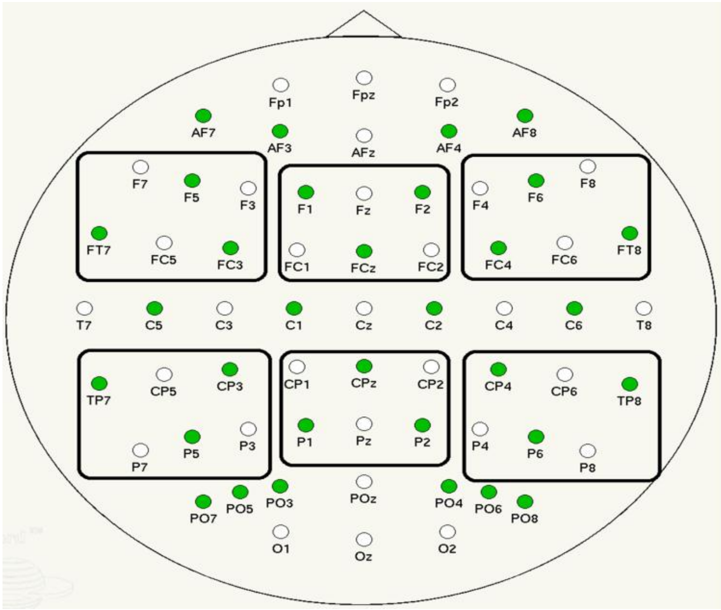


Figure 2.6: Electrode cluster schematic

Average amplitude from individual electrode were pooled together to create clusters of electrodes across 6 scalp regions (Anterior and Posterior). This data reduction technique addresses a family-wise error in dense arrays of electrodes (Oken and Chiappa, 1986).

2.7 Graphic representation

In this thesis, scalp maps have also been presented alongside waveforms demonstrating significant differences in ERP components. ERP graphs can be presented in a number of ways. In a typical ERP waveform graph, time in millisecond (ms) is plotted on the x-axis while microvolt (mv) is shown along the y-axis. Scalp or topographic, maps provide information on the general pattern of activation across brain areas and are usually made by subtracting one of the conditions from another at all the recorded electrode sites at any one point in time (Friedman & Johnson, 2000).

Chapter 3: Role of level of processing in modulating emotional memory

3.1 Overview

Information is processed on three levels: surface, semantic, and self-referential. The objective of the studies reported in this chapter is to compare three encoding strategies in terms of their capacity to mediate the relationship between emotion and memory. First, a word corpus study was conducted to prepare a set of emotionally negative and neutral words to be used as stimuli in subsequent experiments. The aim of this study was to match words on qualitative (abstract/concreteness, image-ability and context availability) and quantitative (word length, the number of syllables and word frequency) characteristics. There then follow two behavioural experiments. The first experiment compared shallow/surface encoding with deep/semantic encoding strategy. While in the second experiment, semantic/deep encoding was paired with self-reference encoding to see its influence on emotional memory. The findings of these two studies revealed no preference for any level of elaboration over the other in the modulation of emotion memory.

3.2 General Introduction

Elaboration is a powerful strategy for learning and memorizing new information in daily life (Craik & Tulving, 1975). In the context of this study, elaboration means relating new information to existing knowledge to make it more meaningful (Craik, 2002). For instance, an individual can elaborate on the digits "9 and 11" in a phone number by relating it to the "9-11" attack on the World Trade Centre to memorize it correctly. Meaning-based information and events are processed at a deeper level and tend to produce stronger effects on memory than meaningless or shallow processing (Craik, 2002).

An individual can process information at different levels of elaboration, ranging from high to low. The lowest level of elaboration, shallow/surface processing of information, occurs when individuals pay attention to the superficial details of a stimulus, such as its structure, appearance, colour, brightness or shape instead of its meaning. In contrast, a high level of elaboration occurs when an individual focus on the meaning of a stimulus, thereby producing a more meaningful or deeper analysis of the information (Craik & Tulving, 1975). Both levels of elaboration affect memory differently, as elaborative encoding is superior to non-elaborative/shallow encoding in enhancing memory. This elaborative processing model is based on Craik and Lockhart's (1972) "level of processing" framework for memory and on a seminal empirical paper by Craik & Tulving (1975).

Craik and Lockhart's (1972) "semantic elaboration" model for memory were challenged by another elaborative strategy, the self-reference elaboration (SRE) (Rogers, *et al.*, 1977, 1979; Keenan & Baillet, 1980), which appeared to take precedence over deep/semantic processing. In self-reference elaboration, individuals process new information by linking it to their own personal experiences, attributes, and thought processes (Klein & Kihlstrom, 1986). For instance, the memory of pictures showing a fire, a bomb blast, a murder, an award ceremony, a wedding day, or the birth of a child, might be made stronger if these events are meaningful to the individual and are linked to personal experiences. Hence, memory might be enhanced even above semantic processing if a stimulus or event is processed in a way that relates it to the self (Glisky & Marquine, 2009). From empirical evidences across several fMRI, ERP and EMG investigations, as well as from the behavioural literature, it is known that Craik and Lockhart's (1972) level of processing and self-reference (Conway & Dewhurst, 1995; Craik & Tulving, 1975; Rogers, Kuiper, & Kirker, 1977) are robust mediators of memory enhancement. However, the findings of these studies were inconsistent and relied heavily on studies in which neutral pictures or words were used as stimuli. In the emotional memory literature, few studies have explored elaborative processing, such as deep/semantic and self-reference processing, using emotional stimuli to investigate the phenomenon of emotion-enhanced memory (EEM) (Fujita, 1998; Hamami, Serbun, & Gutchess, 2011; Klein & Kihlstrom, 1994; Yang, 2011; Dulas, 2011; Symons & Johnson, 1997). Consequently, it is still unknown if the memory-enhancing effects of elaborative processing are also reliable for emotional stimuli.

The current studies address this issue by asking the question, "If elaborative processing does in fact enhance emotional memory, which of the three degrees of elaboration most strongly mediates the relationship between emotion and memory". An ERP investigation would further enhance the understanding of the EEM effect since event-related potential (ERP) correlates of each level of elaboration for emotional stimuli have not been studied systematically or comparatively. Therefore, the aim of this project was to investigate the behavioural and ERP basis of the elaboration model for EEM. An investigation into the relatively less-explored but important cognitive factors might help provide explanations that can be used to develop a mediation model for the *Emotion-Enhanced Memory* (EEM) phenomenon. The rest of this chapter provides a detailed account of the two behavioural studies. Two levels of elaboration were tested individually in each experiment. This was to avoid unnecessary lengthy behavioural and subsequent ERP experiments. The aim was to demonstrate behavioural effects and to conduct a follow-up ERP study if it was warranted by the behavioural results. In the first experiment, participants were asked to process emotionally negative and neutral words under shallow and semantic encoding conditions.

Then, semantic elaboration was compared with the so-called highest level of elaboration (self-reference) in the second experiment.

3.3 Experiment 1: Semantic elaboration versus shallow processing

3.3.1 Introduction

The effects of semantic elaboration on emotional stimuli have been investigated by a variety of elaborative tasks, stimuli, and two encoding types: incidental and intentional (Xu, Zhao, Zhao, & Yang, 2011). Specifically, the animate/inanimate judgement task (Kensinger & Schacter, 2006; Richardson, Strange, & Dolan, 2004), abstract/concrete judgement task (Kensinger & Corkin, 2004), and valence rating (Cahill et al., 1996; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Dolcos, LaBar, & Cabeza, 2004; Hamann, Ely, Grafton, & Kilts, 1999) have demonstrated a reliable effect on stimuli. However, only a handful of these studies used semantic elaboration to test assumptions of the level of processing (LOP) for the emotional stimuli (Ferré, 2003; Jay, Caldwell-Harris & King, 2008; Ochsner, 2000). Moreover, the findings of these studies had inconsistencies and, therefore, do not provide reliable evidence to support the LOP model for emotional memory enhancement.

Oschner (2000) found that emotionally negative and positive pictures were better recalled than neutral ones under both an affective and a brightness judgment task. Jay et al. (2008) tested emotional memory for verbal stimuli and found that memory for high-arousal taboo words increased under deep encoding, but that memory for non-arousing emotional words did not. Similar findings were obtained in an fMRI study (Ritchey, LaBar, & Cabeza, 2011), which advocated for two discernible brain activation patterns underlying elaboration-based emotional memory formation. The study found greater activation in the prefrontal cortex during the encoding of positive stimuli, but only in the deep processing condition. In the second experiment of the same study, Jay and colleagues found enhanced memory for neutral words over emotional ones. Additionally, Ferre's (2003) study found that memory for negative and positive words was similar under semantic elaboration. A potential explanation for these findings may be that under semantic processing many retrieval cues are available, which not only provide a memory advantage for the emotional material, but also for the non-emotional (Reber, Perrig, Flammer & Walther, 1994).

From a critical analysis of these studies, it appeared that all were affected by some confounding factor. For instance, Jay et al. (2008) was confounded by the semantic relatedness of the neutral words, which may be the reason for the observed enhancement in neutral memory (Xu et al., 2011). In fact, other studies have shown that semantic relatedness is an important factor which might also contribute to enhancing memory (Talmi & Moscovitch, 2004; Deborah Talmi, Luk, McGarry, & Moscovitch, 2007). Another confounding factor in many of these studies was the varying arousal level of the negative and positive stimuli, as was the case in Jay's experiment 1 (Xu et al., 2011).

There is also evidence to suggest that memory of gist and detail of emotional stimuli are also modulated in different ways by LOP. The experiment by Xu et al (2011) demonstrated no advantage in emotional memory enhancement for deep encoding over the shallow. However, they detected memory differences for detail and gist of the stimuli. Details of negative and positive pictures were recalled equally well under both shallow and deep encoding, as compared to neutral pictures. However, the gist of the negative picture was remembered better than neutral pictures only under deeper encoding.

Several studies carried out using neutral stimuli have provided evidence that semantic strategy is superior to shallow encoding in the LOP model. However, when emotional stimuli are involved, it is unknown which encoding strategy is more effective. For example, recent studies have shown that emotional memory (specifically, memory of negative events) benefits more from shallow processing (Dew, Ritchey, LaBar, & Cabeza, 2014; Ritchey et al., 2011). A recent fMRI investigation on pictures (Ritchey, et al., 2011) and words (Jay, et al., 2008), found that participants' emotional memory was enhanced during shallow processing relative to semantic (deeper) processing. To explain the mechanism behind the observed emotional memory enhancement, the authors suggested that shallow processing is analogous to a divided attention condition. Much like when attention is divided, memory for high-arousal emotional stimuli is less affected during shallow encoding (M Ritchey et al., 2011). Support for this mechanism also comes from Bower's network model of emotion (Reber, Perrig, Flammer, & Walther, 1994) which suggests that the emotional component (valence/arousal) is the only retrieval cue available when shallow processing is involved; therefore, memory for emotional stimuli is enhanced while recalling the material encoded under shallow processing. In conclusion, it appears that under shallow encoding, emotional memory is modulated by high-arousal stimuli, regardless of the valence of the stimuli (Ferrer, 2003). Thus, the findings reveal that individuals' memory is impaired with divided attention in case of non-arousing words (Bush & Geer, 2001). Also, the memory advantage for negative, non-arousing words are eliminated when participants encode items while performing an irrelevant task (Kensinger & Suzanne Corkin, 2004). These findings have supported the semantic processing hypothesis, as the mechanism accounts for the memory enhancement effect for negative less arousing stimuli.

Considering the literature 's inconsistent findings, confounding factors, and resultant limitations, for our investigation we selected only non-arousing negative words while carefully controlling for the semantic relatedness of neutral and negative words in each study list. A comparative study was designed to contrast shallow and deep encoding strategies for emotional and non-emotional words, and their subsequent effect on memory recall. We hypothesized that if semantic processing is involved in the emotional modulation of encoding-related activity, then an attenuation of emotional SME effects should be observed in the shallow condition or vice versa.

Words were chosen as stimuli because previous studies found that the superiority of semantic processing holds more for word stimuli than for pictorial stimuli (Intraub & Nicklos, 1985). Both classes of words were selected from Affective Norms for English Words (ANEW) database (Bradley & Lang, 1999a). For the purpose of controlling for unwanted variables, a word corpus study was designed to match word stimuli on all possible linguistic characteristics. For the experimental control, it was vital to hold all characteristics of the words constant, except valence and arousal. As it is conventional in the literature, stimuli (emotional and non-emotional words) were matched for word length, word frequency, number of syllables, word concreteness, abstractness, familiarity, imageability (Kanske & Kotz, 2007; Kissler, Assadollahi, & Herbert, 2006; Padovani, Koenig, Brandeis, & Perrig, 2011) and context availability (Altarriba, Bauer, & Benvenuto, 1999).

In order to match emotional and neutral words on these qualitative and quantitative dimensions, a word rating study was conducted. All the adjectives were excluded from the selected negative and neutral word lists. This exclusion was made in light of the research findings by Klein et al., (1989), who noticed that the reason for inconsistent results across self-referential studies was a failure to distinguish between the type of verbal stimuli used for self-descriptive judgment and autobiographical retrieval. While the majority of the self-descriptive judgement studies used trait adjectives, the autobiographical retrieval studies used nouns as stimuli. Klein et al. (1989) dissociated findings of self-referential studies on the basis of stimuli used: nouns vs. trait adjectives, to eliminate inconsistencies. The findings of his research revealed that both tasks were independent and self-descriptive, and not related to self-relevant autobiographical retrieval (Stanley, Klein, Loftus, & Burton, 1989).

3.3.2 Study 1a: Normative Word Rating Study

3.3.2.1 Introduction

Words were selected from the Affective Norms for English Words (ANEW) database (Bradley, Greenwald, Petry, & Lang, 1992), which has been widely used in emotion studies

(Ritchey et al., 2011; Scott, O'Donnell, & Sereno, 2014; Stevenson, Mikels, & James, 2007; Trammell & Clore, 2013; Vigliocco et al., 2014; White, Kapucu, Bruno, Rotello, & Ratcliff, 2013). The ANEW database consists of a total of 1,035 positive, negative and neutral words. It has a bipolar scale for valence and mean scores ranged from negative (low) to positive words (high) (M = 1.25 to M = 8.82). Only negative and neutral words were taken from this database. To separate the positively valenced items from the negative and neutral, median scores (Neutral 5.30, Negative 3.28) were used as a cut-off point. Mean valence and arousal scores of the selected negative words ranged from Valence: 1.25 - 3.28; Arousal: 2.64 - 8.17, and neutral words ranged between 4.02 - 6.42. The selected emotional and neutral words were significantly different on normative ratings given in the ANEW manual for the valence $t(238) = 31.30$, $p < .01$ as well as the arousal dimension $t(238) = 8.67$, $p < .01$. Mean valence rating for negative and neutral words ranged from 2.67(.67) to 5.44 (.69) respectively. Arousal rating ranged from 4.76 (.61) to 4.76 (.61) respectively.

The main objective of this corpus study was to match words on the linguistic characteristics related to word processing and memory, as well as three qualitative ones (abstractness, imageability, and context availability).

Negative and neutral words were matched on three quantitative dimensions (word frequency, the number of syllables, and the number of letters in each word) because they might serve as confounding variables in enhancing or impairing memory. A high or low frequency of word usage influences word processing speed, such that high/low frequencies are processed faster and recalled greater than words that are used moderately (Diana & Reder, 2006; Guo, Zhu, Ding, Fan, & Paller, 2004; MacLeod & Kampe, 1996). The Medical Research Council (MRC) Psycholinguistic Database provided word frequency norms by Kucera and Francis (1967), which are frequently reported in the literature. However, we used a revised version of Kucera and Francis' word frequency rating (Brysbaert & New, 2009) since their word frequency norms, which are available in MRC (Wilson, 1988), did not provide frequencies for all the selected ANEW words. Finally, according to the revised version of Kucera and Francis' word frequency rating (cited in Brysbaert & New, 2009), all the selected ANEW words had a frequency occurrence rate between 1-30 per million. Additionally, word length and number of syllables impact human memory. Therefore, negative and neutral words were matched for word length (4-10 letters) and number of syllables (1-4). The norms provided in MRC (Coltheart, 1981; Wilson, 1988) were used as a measure of word length and number of syllables. After matching words on quantitative dimensions (word length, the number of syllables, and word frequency), we were left with a dataset of 320 words (160 negative and 160 neutral).

The next step was to match words on three qualitative dimensions (abstract/concreteness, imageability, and context availability) frequently reported in the literature as potentially confounding in emotional memory enhancement. Because the MRC database did not provide abstract/concreteness or imageability ratings for all the selected ANEW words, it was decided to conduct a separate study to obtain ratings on abstract/concreteness, imageability, and context availability dimensions for the ANEW words. It was also decided that if words were not fully matched on these dimensions, then they might be further used as a covariate in the study. It was an online word rating survey designed on Bristol Online Survey (BOS) tool, https://www.onlinesurveys.ac.uk/.

3.3.2.2 Method

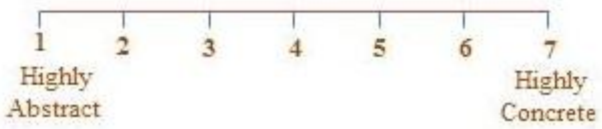
3.3.2.2.1 Participants.

A total of 45 participants (14 males and 31 females) were recruited from the Psychology Department participant pool, which included students, academic and non-academic staff at Durham University. Their ages ranged from between 18 and 40 years. The mean ages of the male and female participants were (*M* = 25.06, *SD* = 2.10) and (*M* = 22.75, *SD* = 4.65) respectively. They were remunerated £5 for their participation. All participants were native English language speakers. They were assigned a survey I.D. to safeguard their identities. The study was approved by Durham University Psychology departmental committee. Upon showing their willingness to participate in the word rating study, they were sent a web link to the online survey.

3.3.2.2.2 Design

This online word rating study was a between subjects' design. Fifteen participants rated a single dimension. Participants were asked to rate word abstract/concreteness, image-ability, and context availability on a seven-point scale. The instructions and examples were in line with Altarriba, Bauer and Benvenuto's 1999 study. The specific instruction and scales are as follows:

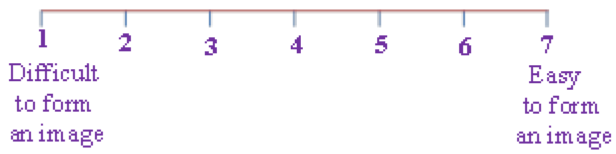
> <u>*Abstract/Concreteness*</u>
>
> *"You will see a list of words below. You have to rate the words according to how abstract or concrete they are. For your understanding, concrete words are defined as the words that denote something material and represent an actual substance or thing. Abstract words refer to something considered apart from some material basis or object.*



Your task is to enter a number between "1" to "7" next to each word. Please use the given scale to rate the words. For example, you might rate the word "chair" as a 5 or 6 or 7, considering it concrete, while the word "charity" might be rated a 1 or a 2 or 3 being abstract (4 is a neutral point).

<u>Imageability Dimension</u>

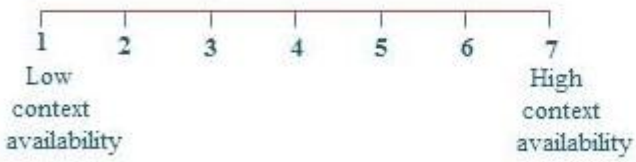
You will see blocks of words below. Your task is to rate each word on imageability dimension. For your understanding, imageability means how easy or difficult it is to form an image of the given word.



For example, some words are easy to imagine, such as "flag" and some are difficult to imagine, such as "soul." If it is difficult to form an image of the word, you can rate it a 1/2/3; on the other hand, if it's easy to form an image, then you can rate it as 5/6/7 according to its strength (4 is a neutral point) on the scale."

<u>Context Availability</u>

"When we read or hear a word, it brings some context to mind based on our experiences and exposures. If a word 'immediately' brings some context to mind, then the word has a 'high' context availability. If it takes some time to come up with a context, then the word has a 'low' context availability. Here, you have to rate each word on a context availability dimension. Please use the scale to rate how quickly each word brings a particular context or circumstance to mind.



For example, the word "cry" might receive a rating of 6 or 7 if you immediately think of a baby crying in his crib. In contrast, the word "heritage" might be rated a 1 or a 2, since it might take longer to come up with a context in which the word might appear.

3.3.2.3 Procedure

First, the participants who responded to initial request to participate in the experiment were sent a 'Participant Information sheet' (see appendix B) and consent form (Appendix A) to see if they still willingness to participate after reading information sheet which contained few examples of the emotional words to be used in experiments. The participants were sent a web link to the survey after getting a signed informed consent which showed their willingness to participate. The approximate duration of the rating study was 20 minutes. They were given £5 for their participation or course credit worth 20 minutes if participants selected from psychology participants pool.

3.3.2.4 Results

After ratings had been received on the three dimensions, words were classified as high or low on abstractness and context availability, and difficult/easy on the imageability dimension within each category of negative and neutral words. The median was used as a cut-off point for this classification. The purpose was to make sure that there was an equal distribution of high and low levels of rating dimensions across the word categories. Out of 160 negative and 160 neutral words, 120 in each category were found to be the best-matched words. Further, data were tested through an independent sample test to see if the rated words were also matched statistically. The non-significant t-tests were considered as indicative of matching, as they signify that the negative and neutral words are reliably matched on all of the word properties except context-availability. See figure 3.1 for mean rating scores across all dimension of words.

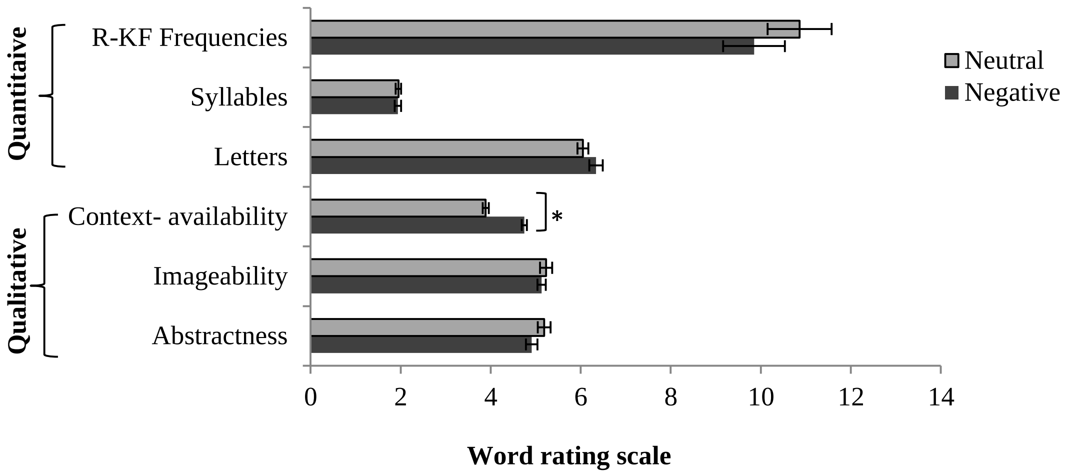


Figure 3.1: Mean rating scores on qualitative and qualitative dimensions of ANEW words

Emotionally negative and neutral words selected from Affective Norms for English words (ANEW) database matched on qualitative and quantitative linguistic dimensions. The figure shows that words were matched on revised Kucera and Francis' (R-KF) word frequency rating, the number of syllables and letters as well as on quantitative dimensions such as image-ability and abstractness. However, rating showed the higher mean score on context availability dimension for negative words compared to neutral. Error bars show standard error of the mean. Note: *p < .05

Negative and neutral words were matched on all three quantitative rating dimensions, i.e., the frequency of usage, the number of letters, and the number of syllables, as the t-test revealed non-significant ($p > .05$) differences. Out of three qualitative rating dimensions, negative and neutral words were matched on abstractness $t(238) = 1.34$, $p = .179$ and imageability ratings $t(238) = .508$, $p = .612$, but not on context availability $t(238) = 10.01$, $p < .01$, as it yielded significant differences between the negative and neutral word categories. These results mean that the context of negative words ($M = 4.76$, $SD = .61$) was easier to bring to mind than the neutral context ($M = 3.89$, $SD = .72$).

Table 3.1: Correlation coefficients between qualitative dimensions of ANEW words.

	1	2	3	4	5
1. Valence	-	-.520**	.077	.094	-.508**
2. Arousal	-	-	-.177**	-.085	.460**
3. Abstract-ness	-	-	-	.816**	.308**
4. Image-ability	-	-	-	-	.432**
5. Context-Availability	-	-	-	-	-

$^{**}p < .01$

The correlation between measures revealed a number of significant results (see table 3.1). Valence appeared to be inversely related to arousal and context availability dimensions (r = -.508; -.520 respectively) but not to the abstractness and imageability of the words. Arousal, on the other hand, was positively correlated with context availability (r = .460) and inversely correlated with the abstractness of the word (r = -.177) which suggest that the high arousal words are less abstract. Abstractness was strongly positively correlated with Imageability and moderately related to context availability (r = .816, .308, respectively). In sum, the correlational analysis showed that all the dimensions have significant positive inter-correlations except arousal which appeared inversely associated to valence and abstractness of the words.

A revised version of Kucera and Francis' word frequency ratings (Brysbaert & New, 2009) was used in the current study. A significantly high correlation (r = .328**) between old and revised versions in the current study validated the use of revised (Brysbaert & New, 2009) norms for Kucera and Francis' word frequency ratings.

3.3.2.5 Conclusion

In sum, negative and neutral words were closely matched on abstract/concreteness, image-ability, word length, and a number of syllables and word frequency dimensions, but not for the context availability dimension, which would be further used as a covariate in the study. A set of 240 words (120 negative and 120 neutral) was prepared for the subsequent two studies: semantic vs. shallow and semantic vs. self-reference encoding. A final list of all the emotionally negative and neutral words along with words used as fillers to deal with primacy and recency effect is given in Appendix C.

3.3.3 Study 1b: Shallow vs. Semantic Encoding

A detailed theoretical background has been given in the introduction above. Generally, this study aims at comparing two type of encoding strategies, i.e. shallow versus semantic/deep, with a focus on the recall of emotional words. This specific prediction is that the memory of emotional words would enhance under shallow processing rather than semantic processing.

3.3.3.1 Pilot study

A pilot study was conducted to test the efficiency of the encoding tasks selected for the study. Six participants were recruited via the undergraduate participants' pool. In a between-group design, each group was presented with one of the two encoding conditions, shallow and deep. The task of the participants was to look at a list of emotional and neutral words, which they had to encode under shallow and semantic encoding instructions. In shallow encoding, participants were asked the question, "Does this word contain 'an' in it?" The aim of the semantic encoding task was to tell if the word was abstract or concrete. They had to respond to each task by pressing keys specified for "yes or no."

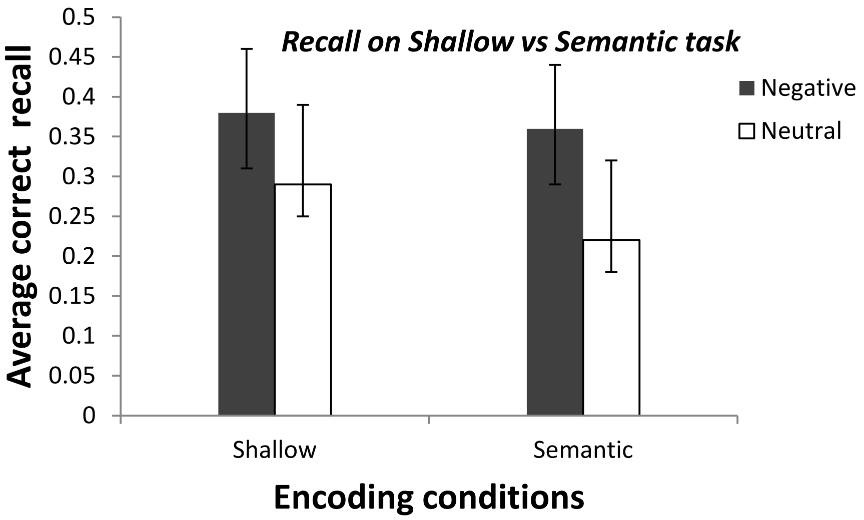


Figure 3.2: Mean scores under shallow and semantic encoding condition -Pilot study. Findings revealed a non-significant difference between for recall memory under shallow and semantic encoding task.

Emotionally negative and neutral words each 120 in number were presented to both encoding groups in a series of eight blocks. After each block, first they had to do a distraction task (solving simple math equation), then they were asked to recall as many words as they can on a word recall sheet. The number of recalled negative and neutral words under each encoding strategy served as the dependent variable. Participants' memory scores were put into analysis. Independent sample t-test revealed a non-significant difference between emotional and neutral words recalled across shallow and semantic encoding strategies $t(4)= .154$, $p = .885$; $t(4)= .088$, $p = .518$. These findings highlighted the need for a few important revisions in the experimental design. Participants were also asked if they used some strategy to remember words. Therefore, it appeared that the shallow encoding task was quite easy and less engaging, which allowed participants to use memorizing strategies that might have contaminated memory performance.

In light of the findings from the pilot study, three main modifications were made in the experimental method. First, the distraction task was presented for 60 seconds only (previously it was 180 seconds long); second, the words in each list were randomised in an attempt to make them less-related semantically; and third, the shallow encoding task, “Does the word contain ‘an’ in it?” was replaced with “Is the word in ascending order alphabetically?” to make the shallow task more difficult. The semantic task remained unchanged.

3.3.3.2 Main study

3.3.3.2.1 Participants

Twelve female participants were recruited for this study. Age of the participants ranged from between 18 and 21 years, and the mean age of the participants was (M = 19.41, SD = 0.99). All participants were reported to be right handed, native English language speakers, and had no history of neurological or psychiatric disorders. They were remunerated £12 for their participation. Data from the two participants were excluded from the analysis, as their scores were behavioural outliers and their mean scores were found 3 SD above mean.

3.3.3.2.2 Design

In this between-subjects design, participants were randomly assigned to the groups. They had to encode emotional and non-emotional words under either shallow or semantic encoding. The aim of the study was to compare both encoding strategies to see the effect on memory recall. It was hypothesized that if semantic processing was involved in the emotional modulation of encoding-related activity, then an attenuation of emotional SME effects should be observed in the shallow condition or vice versa. Specifically, we predicted that negative emotional memory would be enhanced more during semantic encoding than shallow processing. The experiment consisted of eight blocks with 30 trials per block. An equal number of emotionally negative and neutral words were arranged per block. In the memory literature, it has been observed that individuals tend to remember what comes first (primacy effect) or what is presented at the end (recency effect) of a list of stimuli (Erk, et al., 2003; Greene, Prepscius & Levy, 2000). To control for the primacy and recency effect in this study, two words were used as filler at the start and end of each word list (see fillers in Appendix C). The order of the word presentation was randomized within each list. The words were displayed in black with 24 font on a white background. Words were displayed on the screen for 2000ms. Prior to that, a fixation (+) slide was shown and then the encoding task slide remained on the screen until participants responded by pressing relevant keys. The process of a single trial for semantic and shallow encoding is shown in figure 3.3 and 3.4 respectively.

3.3.3.2.3 Procedure

Participants were provided ample information with highlights of the experiment in an 'Information sheet' before their participation (see Appendix D). Upon their willingness, they were invited to participate in the experiment. On their arrival in the lab, they seated comfortably, at a distance of approximately 70cm away from the 19" computer screen. Stimuli presentation and response data were controlled using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) running under Windows 7 on a Dell latitude 6500 desktops. Before their participation in the main experiment, they were given detailed instructions and completed ten practice trials to familiarise themselves with the experimental task. For the shallow encoding, the task was to find an alphabetical relation between the first and last letter of each presented word. A word was considered in ascending order if the first and last letters were in alphabetical order (A-Z), such as "clear," because "c" comes before "r" alphabetically. A word was considered in descending order if in reverse order (Z-A) such as "hope," because "h" comes after "e" alphabetically. The specific question was, "Is the word in ascending order?" Participants had to press key 1 on the response box for 'Yes' and 2 for 'No.' They were also instructed that if they came across a word which starts and ends with the same letter (such as "status"), they were to consider it to be in descending order, not in ascending order (*see* Appendix E for detailed instruction). An illustration of the shallow encoding trial is given in figure 3.3 below.

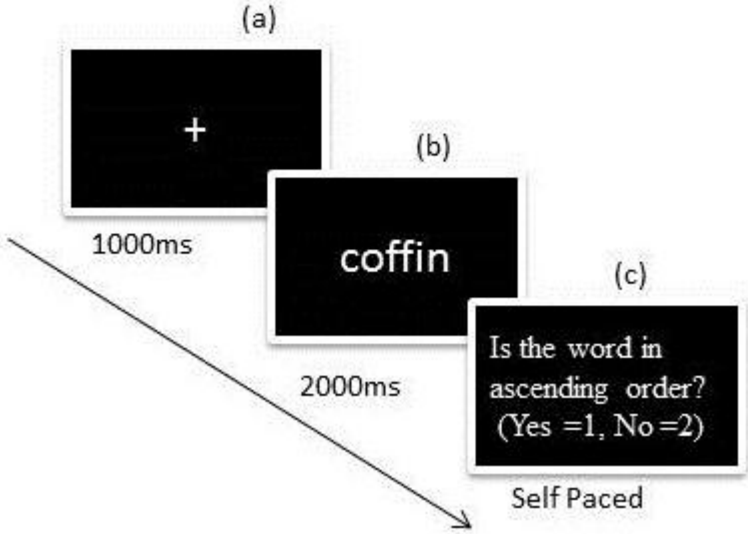


Figure 3.3: A schematic illustration of shallow encoding.
The experimental procedure of shallow encoding. (a) A fixation point was presented for the 1000ms. (b) Emotional and neutral words were presented for 2000ms. (c) Shallow encoding task appeared on the screen after picture display with no quick reaction required from participants to respond to the task.

For the semantic encoding, the task was to identify whether the presented word was abstract or not. For their understanding, abstract words were defined as something considered apart from some material basis or object, such as the word "intelligence" or "soul," etc. Abstract words were contrasted with concrete words, which denoted something material and represented an actual substance or thing, such as table or mug, etc. (*see* Appendix F for detailed instructions). In response to the question, "Is it an abstract word?", they were requested to press 1 for 'Yes' and 2 for 'No.' The sequence of a single trial for semantic encoding is provided in the figure 3.4 below.

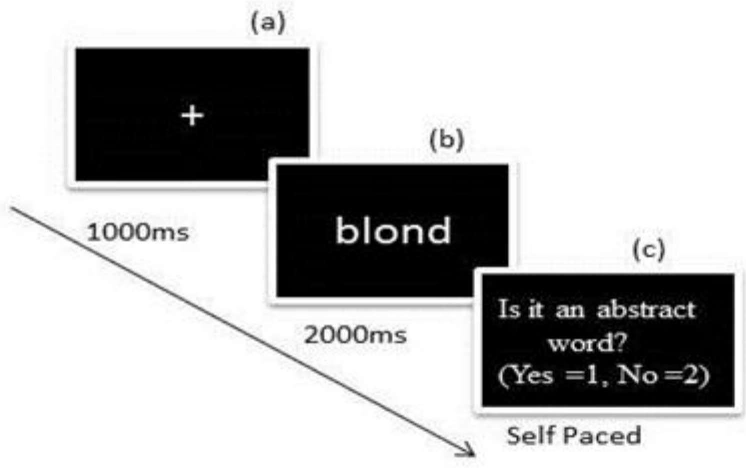


Figure 3.4: A schematic illustration of semantic encoding

The experimental procedure of semantic encoding. (a) A fixation point was presented for the 1000ms. (b) Emotional and neutral words were presented for 2000ms. (c) Encoding task appeared on the screen after picture display with no quick reaction required to respond to the task.

After completing each block, participants were provided with a computerised distraction task and solved mathematics equations as correct or incorrect by pressing specified keys, (1 for "Yes" and 2 for "No"). An example of the equation includes, (8+4-9) =2 and (36/18)=1. For a list of equations presented as distraction task, see Appendix R.

The duration of the distraction task was 60 seconds, and they were required to do as many sums as they could. The distraction task was followed by a recall of words. Participants were given 5 minutes to recall as many words as they could on a 'recall sheet' provided for this purpose. It was important that they reported every word that they remembered. Participants were debriefed after the experiment.

3.3.3.2.4 Results

Recall memory performance of the participants was recorded. Words used as fillers were excluded from the analysis. Remembered words were subtracted from the total number of words to get the score of forgotten words. Data were analysed using the Subsequent Memory Paradigm (SMP). First, memory scores were calculated for emotionally negative and neutral words by subtracting the forgotten from the remembered items across both encoding conditions. Then, an independent sample t-test was run to find out the encoding task mediating the relationship between emotion and memory enhancement. Findings revealed a non-significant difference between words recalled under the shallow and semantic encoding regarding: negative words, $t(8) = .654$, $p = .532$, for neutral words $t(8) = .1.49$, $p = .175$

Table 3.2: Mean scores of negative and neutral words recalled under Shallow and Semantic encoding conditions

Encoding task	*M (SE)* Negative	*M(SE)* Neutral
Shallow	34.6 (3.96)	20 (3.33)
Semantic	38 (3.36)	26.4 (2.71)

Descriptive statistics in table showed that overall participants recalled more negative words across conditions as compared to neutral. However, frequency of the correctly recalled negative and neutral words was greater in semantic condition. Results are displayed in figure 3.5 below.

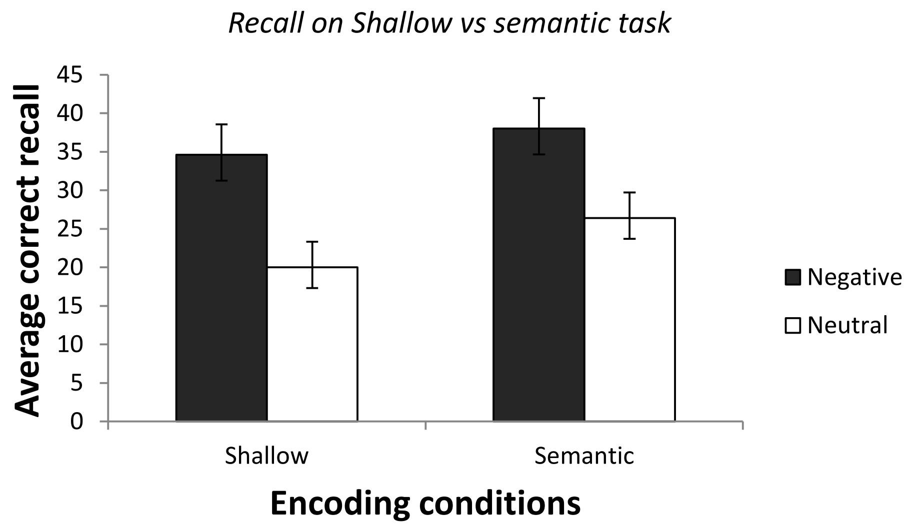


Figure 3.5: Mean recall rate by encoding conditions and valence. Error bar represents the standard error of mean.

3.3.3.2.5 Discussion

The prediction regarding the enhanced performance under semantic encoding yielded was not supported by the findings. The prediction of this experiment rested on the elaborative processing hypothesis, which asserts that elaborating on a word facilitates item-specific information, and provides multiple routes of information retrieval. Findings revealed that semantic elaborative processing did not facilitate encoding of the emotional information above neutral ones. These findings might well be explained by the organizational processing hypothesis, provided that cognitive resources such as elaboration and semantic relatedness and other linguistic characteristics were well controlled for both neutral and emotional words. Therefore, the memory difference for the emotional words was not higher than that of neutral words.

There are several limitations of the current study; for example, in an effort to make the paradigm work, the shallow encoding task was modified so that the words were purely processed at shallow level. It was noticed that the modified shallow encoding task was not only effective in reducing the use of other strategies to memorize words, but also in processing them at shallow level. However, this resulted in a low frequency of recalled words in shallow neutral condition, specifically.

In addition, a limitation relates to the time duration of the word display. From the findings of the pilot study, it was observed that 1,000ms and 1,500ms time durations for word display adversely affected the encoding of neutral words for shallow condition and as a result, participants recalled less than 12 words. To fix this issue, in this study, a 2,000ms word display time duration was used. This modification addressed the low-frequency issue in the neutral condition, but at the same time, it reduced the difference between negative and neutral recall in the shallow condition, which was central to the question under investigation. These limitations were a matter of concern for an ERP study where a minimum number of required trials is 12.

3.4 Experiment 2: Semantic vs. Self-Referential encoding

3.4.1 Introduction

A number of studies have demonstrated that the more elaborative the cognitive framework, the better the retrieval (Kail, Robert, & Levine, 1976; Klein & Loftus, 1988). The most elaborative framework an individual possesses is the knowledge of the self (Klein & Kihlstrom, 1986; Klein & Kihlstrom, 1986). In the behavioural literature, it is well documented that information which is processed with reference to the self is remembered better than semantic, structural, phonemic or any other reference (close/distant), or with no reference at all (Zhu & Zhang, 2002). Hence, the self is an elaborated and powerful knowledge structure that has many different aspects, such as autobiographical information, physical appearance, personality traits, family relations, group affiliation, values, goals, professional association, and experiences (Bless, Fiedler, & Strack, 2004). These aspects facilitate encoding of information in the memory system by developing associations or by promoting elaborative processing (Klein, 2012a; Klein, 2012b).

The role of self in enhancing memory was first explored by Rogers, et al. (1977) in an attempt to provide a preference of the Self-Referential Effect on semantic processing, which was established by Craik & Tulving (1975) in their Depth of Processing model. Rogers presented a series of trait adjectives and asked participants to rate words with reference to their meaning (semantic), composition (structure), and sound (phonemic), and with reference to the self. Reference to the self, was actually an addition to the Craik and Tulving's (1975) model of Depth of Processing. Participants showed better memory for the self-descriptive trait words than for those encoded under structural and semantic tasks used in the standard levels of processing experiment. Rogers et al. (1977) named it the "Self-Referential Effect." However, a question still open to investigation, and a focus of this experiment is: how well does the self-reference effect generalize to emotional stimuli? It is not yet clear or well-established as to how far self-reference (compared to semantic encoding) helps explain the mediatory role for emotion-enhanced memory (EEM).

A distinct self-referential effect (SRE) has been found in a number of studies conducted over a period of time in different labs (MacCaul & Maki, 1984: Breck & Smith,1983; Halpin, et al.,1984; Hull, et al., 1988; Katz,1987; Muller, et al.,1991; Register & Kihlstorm,1987; Sutton, et al., 1988; Symons, 1990). However, there is disagreement among researchers on the mechanism that underlies enhanced memory advantages for the material encoded with reference to self. Several cognitive mechanisms have been suggested for the self-referential effect, such as elaboration (Klein & Loftus, 1988; Rogers et al., 1977), organization (Klein & Kihlstrom, 1986; Klein & Loftus, 1988), evaluation (Ferguson, Rule, & Carlson, 1983; Klein & Loftus, 1988) and cognitive cueing and distinctiveness (Bellezza, 1984). However, two mechanisms emerged so far on the basis of studies by Klein & Loftus (1988) and Symons and Johnson's (1997) meta-analysis: elaborative processing and the organizational processing hypothesis.

Evidence regarding the strength of the SRE as a powerful encoding strategy rested on the assumption that self is a "superordinate schema," a vibrant and elaborated cognitive structure (Rogers, et al., 1977, 1979; Keenan & Baillet,1980). Bower and Gillian (1979) challenged the mediatory role of self-schema in SRE. Their research findings indicated that relating information to any well-differentiated person (such as a father or wife) might result in memory gains analogous to SRE. Therefore, it is not the self-schema that mediates the relation between SRE and memory; rather, memory is improved by relating the information to some highly developed conceptual network other than the self (Maki & Macaul, 1985; Bower & Gilligan, 1979; Brown, et al., 1986; Bradely & Methew, 1988; Ferguson, et. al., 1983; Ganellen & Carver, 1985; Muller, et al., 1986; Mogg, et al., 1987). It is also worth noting that this memory advantage decreases as the closeness of the relationship decreases. For instance, memory performance decreased in the condition where participants were asked to relate the traits to "president" or "prime minister" or any distant person (Bower & Gilligan, 1979).

Studies also attempted to show that SRE is associated with the experience of remembering in contrast to knowing (Conway & Dewhurst, 1995: Hirshman & Lanning, 1999) using the Remember-Know (R/K) paradigm. It is because the recollection experience certainly entails a self which has experience of recollection, whereas, in contrast, memory judgments based on familiarity do not necessarily require self-reference during remembering. According to this reasoning, the SRE will only be present for those items which are judged as recollected. Thus, by controlling the different levels of self-reference (a reference to self, significant others, and distant others), one can get different recollections at different levels. Autobiographical elaboration encourages connections between the processed stimuli and the self. As a result, memory for those items is enhanced, which is elaborated by the autobiographical content in contrast to the processing (Rogers et al., 1977; Bush & Geer, 2001).

Not all the studies which focused on SR tasks resulted in memory benefits. For example, in some studies, when the SR task was compared with no reference to others, it produced higher recall (Lord, 1980) in some, but in others it failed to enhance memory (Bower & Gilligan, 1979). Moreover, words encoded with the SR task showed greater recall advantage over semantically-encoded material in a few studies (Klein & Loftus, 1988; Warren, Chattin, Thompson, & Tomsky, 1983); in contrast, a number of others did not find this effect ((Velichkovsky, 1999). In an attempt to rule out the reason for inconsistent results across self-referential studies, Klein et al. (1989) noticed that SRE has been investigated using two different tasks as a manipulation of self-reference; one is self-descriptive, and the other is an autobiographical encoding task.

Self-descriptive tasks were those where participants were asked to relate the adjectives/trait words to the self. In contrast, in autobiographical tasks, participants are asked to relate the words to their personal experience. Linguistic characteristics (nouns/adjectives) of the verbal stimuli used in both studies were also different. In self-descriptive studies, words used as stimuli were adjectives, while in autobiographical studies they were predominantly objects/nouns. When Klein et al. (1989) dissociated self-referential literature on this basis, most of the inconsistencies were eliminated. It was noticed that in the self-descriptive studies, a standard self-referential task had been used widely (that is, “Does this trait describe you?”). However, regarding the SR autobiographical task, there was variability in studies. Some examples of this variability have been reported here. For example, Warren, Chattin, Thompson, & Tomsky (1983) asked participants to remember a personal episode involving the object or a picture of the object. In other instances, Klein and Loftus (1988) instructed the subjects, “to indicate for each word whether it brought to mind an important personal experience by circling yes or no on a response sheet” (p.7). Bower and Galligan (1979), however, used traits and asked participants, “Can you access a personal experience in which you exemplified this trait?” (p.427). In another study, nouns were used (locale/small object) with imagery encoding and SR task (experiment 4). Participants were told, “Every self-image should be based on a personal experience from their past, and that in generating the image they should try to ‘re-create the experience’ in their minds” (Brown, Keenan & Potts, 1986) p.903. These variabilities in autobiographical tasks point towards inconsistent results for the effectiveness of SR encoding.

A meta-analysis on SRE highlighted the variability in the type of verbal stimuli used in SR studies (Symons & Johnson, 1997). Meta-analysis revealed that out of a total of 129 studies on SRE, 90 used traits as stimuli and only 37 used nouns in their studies. Moreover, only eight studies have used autobiographical memory as an encoding task for self, and out of these eight, only four studies have used nouns to explore autobiographical memories (for review see; Symons & Johnson, 1997). In brief, self-descriptive and autobiographical retrieval tasks are distinct and independent, and this distinction should be considered in terms of manipulation of the SR task (Klein, Loftus, & Burton, 1989). The current experiment did not target self-descriptive traits, and that is why all the adjectives were excluded from the emotional and neutral word list and only nouns and verbs were retained.

Further, addressing the inconsistent findings for SR task, Klein and colleagues (Klein & Nelson, 2014; Klein, et al., 1989) found that all SR encoding tasks are not analogous in terms of their capacity to enhance memory - only exclusively those who use nouns as stimuli. For example, a strong memory for nouns was found using an SR task, which explicitly instructed participants to link the stimuli to prior personal experience (Klein, 2012b). Evidence for this hypothesis came when two SR encoding tasks were compared, one with and the other without explicit instruction, to the Survival Processing Hypothesis. The Survival Processing Hypothesis actually claimed that on the basis of their findings, survival processing is superior to self-referential processing in enhancing recall of nouns. For participants, the survival task placed emphasis on the thoughts of personal survival while items were encoded (Nairne, Pandeirada & Thompson, 2008; Nairne, Thompson &

Pandeirada, 2007). Klein (2012b) argued that these findings were the result of the specific wording used for the SR task, in which no explicit request was made to the participants for episodic retrieval, which diminished SR benefits for memory. When participants were asked to perform an active episodic retrieval, the memory performance of the SR task appeared to be equal to survival processing (Klein, 2012b).

However, the matter is not as simple; there is evidence for which explicit instruction or evaluation is not a prerequisite for cognitive processing. Self-referential cues proved to be as effective as explicit instructions in a few studies (Kesebir & Oishi, 2010; Rathbone & Moulin, 2010; Turk, Cunningham & Macrae, 2008). In a similar study, researchers found a strong impact on SR encoding when the personal pronoun “my” was paired with nouns for implicit self-referential encoding and the definite article “the” was paired with nouns to produce a non-referential condition (Herbert, Pauli & Herbert, 2011).

In sum, it can be concluded that SRE depends on a number of factors, such as the instructions (explicit/implicit) and the type of verbal stimuli (adjective/ noun). Klein (2012b) suggested that if the words are nouns, then the prerequisite is to use an explicit instruction task emphasizing episodic retrieval. Therefore, in line with his findings and recommendations, the SR task for the current experiment stressed the importance of bringing a personal experience to mind that involved each of the presented nouns.

SR phenomenon was also investigated a number of hemodynamic studies. Cortical midline structures (CMS) appeared to be activated during SR encoding (Northoff, et al., 2006) in the verbal, spatial, and facial domains in general. More specifically, the emotional domain, anterior cingulate cortex, (ACC) and the dorsomedial prefrontal cortex (DMPFC) appeared to be associated with a high degree of self- reference. However, this activation was observed for emotional stimuli regardless of their valence (Herbert, Herbert & Pauli, 2011; Philippi, Duff, Denburg, Tranel & Rudrauf, 2011).

A handful of studies have tried to explore the emotion-self reference interaction, but again, the findings are not consistent across studies. One such study was conducted by Fields and Kuperberg (2012), which investigated the role of attention in deep processing during self-reference encoding. Regardless of the self-reference condition, findings revealed a larger positivity, an index of deep processing for negative words as compared to pleasant words, which were more positive than neutral stimuli. They concluded that emotion and self-reference are both dependent on one another, as both share cognitive processes, such as attention. However, counter evidence was produced by the findings of an fMRI study (Kelley, et al., 2002), which concluded that MPC is specifically involved in SR processing, and self-reference processing is functionally separable from other forms of semantic processing. Another relevant ERP study further produced contradictory results (Herbert, Pauli, et al., 2011). Early large posterior negativity was observed for emotional stimuli but not for neutral ones, regardless of the encoding condition. However, the late positive potential was enhanced for self-referential negative nouns in one study (Herbert, Pauli, et al., 2011b), while only for emotionally pleasant nouns in another study by the same lab (Herbert, Herbert, Ethofer & Pauli, 2010). The authors suggested that SR acted as a filter of emotional material for later higher-order processing. In another study, SR stimuli elicited a longer N1 latency and larger N2 than non-self-referential stimuli. P3 amplitude was also high for SR task. Lateralization for SRE was more prominent on the left side of the brain (Fan, et al., 2011). In self-reference and other conditions, participants recalled highly affect-arousing words more than the non-emotional words (Bock, 1986).

The rationale for conducting this experiment is to devise a working model of emotion-enhanced memory (EEM) - specifically, how emotions and self-reference interact with each other to modulate memory. In line with the literature, it is predicted that if self-referential processing plays a role in emotional encoding over and above semantic processing, then emotional SME effects should be enhanced in the self-referential condition. For the stimuli, a deliberate selection of the nouns from the Affective Norms for English Words (ANEW) database were chosen to investigate whether the SRE, which was already found for the positive and negative adjectives, is generalizable across affectively-valenced nouns too. Furthermore, emotional material has the capacity of capturing the attention (Anderson, 2005; Bradley, Greenwald, Petry & Lang, 1992; Fox, Russo, Bowles & Dutton, 2001; McKenna & Sharma, 1995) like self-referential stimuli (Bargh & Pratto, 1986; Geller & Shaver, 1976; Williams, Mathews & MacLeod, 1996). It is assumed that both share common nodes in the brain. Therefore, it is expected that emotional words encoded with reference to self would amplify the effects and would be processed even more deeply than in the semantic processing, and thus be more likely to enhance memory.

3.4.2 Method

3.4.2.1 Participants

Forty-nine participants were recruited for this study: 17 males, mean age (M = 22.10; SD = 4.19) and 32 females, mean age (M = 20.31; SD = 2.23). Participants' selection and recruitment criterion and procedure were the same as the previous experiment.

3.4.2.2 Design

A between-group research design was employed. Participants were randomly assigned to the conditions (SR = 25, SM = 24). Self-reference encoding was contrasted with the semantic encoding task. The purpose was to investigate whether self-referential encoding mediated the relation between emotion and memory beyond that seen with semantic encoding processing. Task instructions for the semantic encoding were the same as the previous study (see Appendix E). Instructions for the self-reference encoding were similar to Klein (2012b).

> *"You will see a list of words. Please bring to mind an important personal experience involving each of the words presented, and then for each word you will be asked if it was easy to bring an experience to mind. For instance, the word 'sad' or 'despair' may remind you of the times when you felt sadness or despair due to some person, situation or thing; therefore, in one or the other way it may relate to your personal experience. Similarly, the word 'doll' or "care" may be a reminder of some important personal experience in past. For some items it may be very likely you were able to bring an experience to mind. For others, it may be unlikely. It is up to you to decide."*

However, the question part of the Klein study instructions (2012b) was modified somewhat to fit the requirements of the current experiment. The question asked in the current experiment is "*Is it easy to relate the word to a personal experience?*" The rationale behind this additional information was to find out to what extent was it easy for participants to relate a personal experience to the valence category: negative or neutral.

3.4.2.3 Procedure

The experimental procedure was the same as the previous study. On arrival at the laboratory, participants were provided with informed consent and instruction sheets (see appendix A & G). Verbal instructions were also given to make it sure that the participants fully comprehend the encoding task. Participants went through practice blocks to get familiar with the experimental task before participating in the main experiment. In response to the self-referential encoding task, they were asked to press a specified button: '1' for 'Yes' and '2' for 'No.' No time restriction was imposed for the completion of the task. This was done to provide plenty of time for participants to complete ratings at their own comfortable pace. A semantic illustration for this encoding task is given in figure 3.6 below.

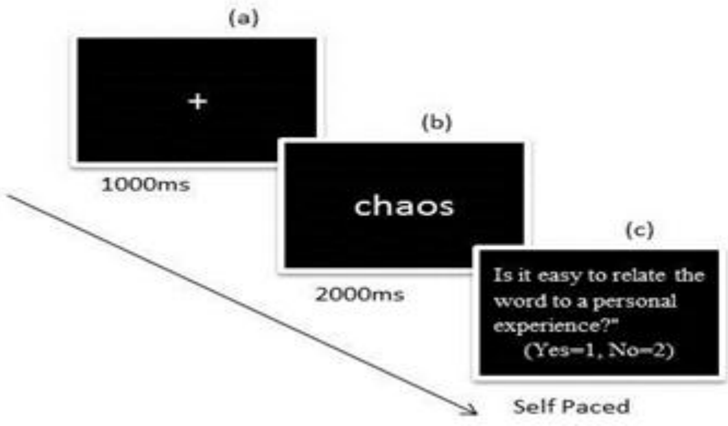


Figure 3.6: A schematic illustration of self-reference encoding

The experimental procedure for self-referential encoding. (a) A fixation point was presented for the 1000ms. (b) Emotional and neutral words were presented for 2000ms. (c) Self-reference encoding task asked the participants that if it is easy for them to relate the word to their personal experience in any way. They responded with 'Yes' or 'No' by a button press. Similar to the previous encoding tasks, no quick reaction was required from participants to respond to this task.

3.4.3 Results

While assessing the recall performance of participants, all the extra intrusive words on the list were excluded. The words that were used as fillers to control for the primacy and recency effects were also not counted as a part of the participants' recall scores. The recall performance was then classified as remembered and forgotten words.

Data was found to be normally distributed using the Shapiro-Wilk test of normality as Negative, $W = .976$, $p = .478$ and Neutral , $W = .964$, $p = .180$ were non-significant. The memory performance was calculated for negative and neutral words by subtracting the forgotten negative and neutral words from the recalled negative and neutral, respectively.

After the assumption of normality was met, number of recalled negative and neutral words were entered into a mixed-design MANOVA with one repeated measure factor (negative and neutral) and two between-subjects' factors, i.e. encoding task: (semantic vs. self-reference) and gender (male and female). Prior to conducting the MANOVA, checks of multicollinearity and homogeneity of variances assumptions were made. Since the dependent measures were moderately correlated, $r = .594$, $p = .01$, this suggested that the assumption of multicollinearity was met. Box's M value was calculated to check whether the covariance between the groups was equally based on Huberty and Petosky's (2000) guideline, using $p < .001$ as a criterion. Box's m test revealed it to be non-significant $M = 9.57$, $p = .495$, indicating the homogeneity of groups was equal. MANOVA findings revealed a non-significant main effect for encoding strategy *F* (2, 44), *p* = .776; Wilk's ^ = .989 η_p^2= .011. This suggested that negative and neutral words encoded using a self-reference strategy did not enhance recall memory above a semantic encoding strategy (see figure 3.7).

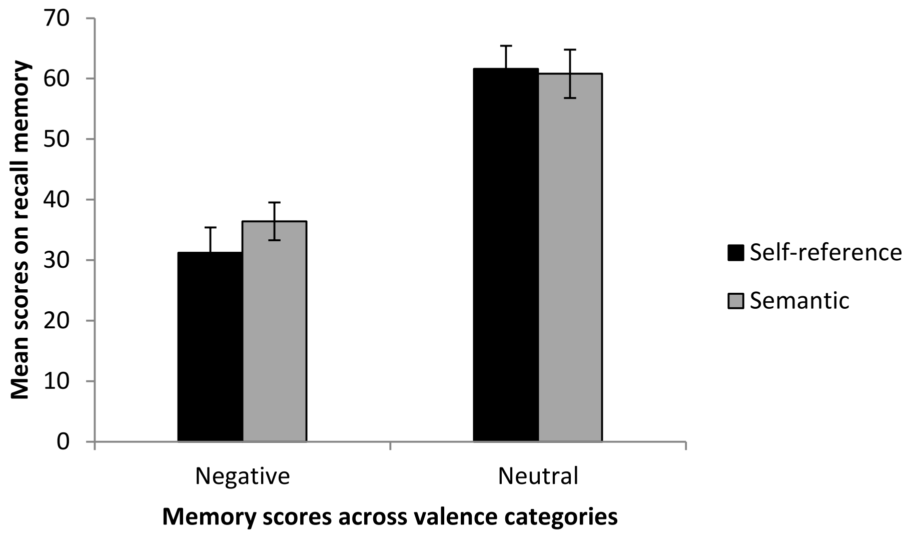


Figure 3.7: Mean scores on recall memory for self-reference and semantic encoding. Mean scores on memory performance yielded no significant difference for Self-Referential and Semantic encoding tasks. Error bars represent standard error of the mean.

The main effect of gender and interaction between gender into encoding strategy also did not reach statistical significance (p > .05).

A reaction time analysis was also conducted on encoding strategies to examine if the participants processed words more efficiently under self-reference encoding than under semantic encoding. Independent t-test findings revealed that participants processed words efficiently (p > .05) under neither of the encoding strategies.

Participants were also asked to rate how easy or difficult it was to bring an event to mind using self-reference tasks. They had to respond with "yes" or "no" to this question. "Yes" responses meant that participants were able to retrieve memory from the past, and a self-reference link was formed successfully. A pairwise t-test revealed no significantly significant difference between the emotionally negative and neutral noun for bringing a personal experience to mind, t(24) =1.50, *p* = .145. It was expected that it would be easy for the participants to retrieve more personal experiences and that the frequency of "yes" responses would be high in negative nouns. However, results countered expectation. The frequency of the "yes" and "no" responses to negative nouns was statistically non-significant $t(24) = .153$, $p = .879$, indicating that the proportion of the "Yes" (15.36%) and "No" (15.84%) responses for emotional nouns encoded with SR task was equal.

3.4.4 Discussion

It was predicted that the memory of the negative words would be enhanced under the self-reference strategy as compared to semantic encoding. However, the findings of the current experiment did not support this prediction.

The behavioural literature well supported the self-reference effect on memory of the verbal non-emotional material. On the other hand, the literature which shows strong SRE for emotional material comes from studies in which positive and negative trait adjectives have been used instead of nouns. It is also known that SRE is sensitive to the manipulation of the words and instructions given to the participants. The SR task used in this experiment was proposed by Klein (2012b). However, unlike Klein's (2012b) study, the findings of this experiment did not produce enhanced recall for the negative words encoded under that specific SR task. There exist two possibilities for these results. First, it is possible that the selected SR task might not have been as effective for emotional stimuli as it proved to be for the non-emotional stimuli in the study (Klein, 2012b). To the best of our knowledge, there is no specific evidence available in the literature in which effectiveness of this SR task has been compared across valence categories.

Second, it is possible that participants could not produce successful episodic retrieval for the majority of negative noun words presented to them. For instance, it might not have been detrimental that participants had experiences attached to most of the negative noun words such as, "scurvy, smallpox, lawsuit, flood, scapegoat or paralysis." These sample words came from the current experiment, and it is possible that not everyone had experience with them. Evidence for this account comes from the findings of the current experiment which asks participants how easy it is to relate the words to the personal experience. Participants responded with "No" to nearly half of the negative words in the list. Looking at the null findings of this experiment as well as others with successful encoding of positive and negative traits using the SR task, it makes more sense that compared to the nouns, it is a lot easier to relate positive and negative traits to the self clearly, accurately, and more efficiently. This factor might be a possible source of failure of the SR encoding task to produce emotional memory advantage in this study. These findings are consistent with previous studies that suggest that encoding of words in memory does not benefit from SR encoding (Aboud, 1980; Higgins & Bargh, 1987; Velichkovsky, 1999).

This study was unique and distinct from the other studies available in the existing literature in that a particular effort was made to match emotionally negative and neutral words on certain linguistic dimensions of the words. This might constitute the third possibility that is controlling the non-arousing words for the three dimensions of the words' image-ability and abstractness/concreteness (except context availability) diminished the effect of the self-reference effect.

3.5 General Discussion

In the present series of experiments, an attempt was made to investigate the mediatory role of elaborative processing in explaining emotion-enhanced memory (EEM), using hierarchal levels of elaboration: shallow, semantic and self-referential. However, findings revealed no preference for any level of elaboration over the other in explaining the emotional memory phenomenon. In the first experiment, emotional memory did not benefit from semantic elaboration, and in the second experiment, self-referential encoding did not enhance memory.

These findings might be partly explained by the organizational process hypothesis. The words in this project were controlled for concreteness and abstractness. Concreteness is a critical organizing factor in semantic memory. Most of the abstract words are also grounded in emotional information. However, an equal number of high and low abstract words in the emotional and negative and neutral categories was organized. Similarly, the other variable, image-ability, was also equally distributed among negative and neutral words. Moreover, the semantic–relatedness of the words presented was also controlled at least within each study list. In this way, all those cognitive resources were equally distributed to neutral information which result in memory advantage for emotional information. Therefore, we attribute the null findings to the constraints on the processing capacity imposed by controlling the linguistic properties of the words. Equal distribution of cognitive resources among both valence categories diminished the memory advantage for non-arousing emotional stimuli. These findings might further be supported by the mediation model of EEM. Because of the variability of methodology in LOP and SR studies, not a single study reported controlling these linguistic properties in their experiment. In this respect, this was the first study ever in which linguistic properties were controlled to study the role of elaboration in emotional memory formation.

Although attempts at expanding the paradigm "level of processing" (LOP) and "Self-reference effect" for emotional stimuli have not been proved fruitful in this project, the development of a word set selected from the ANEW database matched on all important linguistic characteristics, marking an important and unique contribution to the existing emotional memory literature. This set of words can be used reliably for those behavioural as well as ERP experiments in which the aim requires a set of emotional and neutral words selected from the (ANEW) database and controlled for abstractness, imageability, and context availability highly relevant to emotional stimuli. The extent of the contribution from the two behavioural studies, however, requires a good deal of additional research.

The two studies were conducted to set a base for subsequent ERP experiments. Unfortunately, the paradigm did not work well enough to proceed for the ERP studies, initially planned to investigate the electrophysiological basis of emotional memory formation under varying levels of elaboration. Therefore, the direction of the project was shifted to the investigation of the anticipatory/pre-stimulus brain activity involved in emotional memory formation. The rest of the thesis, a set of four studies, one behavioural and three ERP, will focus on this theme.

Chapter 4: Role of anticipation in enhancing emotional memory at behavioral level

4.1 Overview

The behavioural experiment described in this chapter investigates the role of three different anticipatory cue conditions in emotion-enhanced memory (EEM) in humans. The aim of the study was to determine whether or not any anticipatory cues would affect emotional memory or modulate it in some way. Specifically, does foreknowledge of an event influence how that event is recalled later? The experiment was consisted of two phases: the study phase, and the test phase. Emotionally negative and neutral pictures were presented in the study phase under three cue conditions: Informative, Non-Informative, and No-Cue conditions. These three conditions differed on the degree of information they conveyed about the upcoming pictures. Informative cues conveyed specific information about the valence of the imminent pictures while non-informative cue only inform about the occurrence of the picture but provide no specific information about the valence of the picture. The no-cue condition appeared without any cue on the slide. Recognition memory was tested following the study phase. Findings revealed that negative pictures are recognised with greater accuracy but only with informative cues when overall memory accuracy was considered. A subanalysis restricted to R-judgments revealed that this finding extends to non-informative cues (but not the no-cue condition) in the trials in which the stimulus is actually remembered.

4.2 Introduction

The relationship between emotion and anticipation is reciprocal and manifold; that is, emotion influences anticipation and conversely anticipation influences emotions (Castelfranchi & Miceli, 2011). Emotions not only mediate the relationship between stimulus and response by triggering an anticipatory behaviour, but they also signal an underlying mental state, as emotion often induces an anticipatory belief. On the other hand, anticipation relates to emotion through the fulfilment of expectations or invalidation of expectation. Certainty and uncertainty about an event also elicit some emotional response (Castelfranchi & Miceli, 2011). From an evolutionary perspective, the anticipation of aversive events is critical to survival. Since events in everyday social situations do not always occur as expected, the ability to detect unanticipated or partially unexpected dangerous events is crucial for adapting to a rapidly changing environment (Jin et al., 2013).

The development of a theoretical account related to the influence of anticipation on emotional memory is a recent advancement in the EEM literature. In an attempt to probe deeper into how emotional memories are formed, researchers found that the mere anticipation of an emotionally negative situation can activate memory-forming regions of the brain, such as the amygdala and the hippocampus (Mackiewicz, Sarinopoulos, Cleven, Nitschke & McGaugh, 2006; Nitschke, Sarinopoulos, Mackiewicz, Schaefer & Davidson, 2006a, 2006b). In a similar regard, studies have found electrophysiological evidence for a 'Difference due to memory' (Dm) effect during the pre-stimulus phase. Since there are two stimuli in the present experiment, the cue and the picture, the use of the term "pre-stimulus phase (Ps)" seems imprecise. Therefore, for clarity and conciseness, in the current project the pre-stimulus phase is referred to as the "anticipatory phase". Specifically, the anticipatory phase refers to the waiting period between the cue onset and the presentation of the negative/neutral picture stimulus. During the anticipatory phase, the difference in neural activity of subsequently remembered and forgotten pictures is referred to as Pre-stimulus Dm effect (Ps-Dm effect). The studies have found a reliable Ps-Dm effect during the anticipatory phase, but only at the neural level (Galli, Wolpe, et al., 2011). Findings of the similar studies suggest that the anticipation of aversive or gruesome events might be another cognitive factor that contributes to EEM (Galli, Griffiths, et al., 2012; Mackiewicz et al., 2006b; Rademacher et al., 2010). Although these empirical findings are encouraging but what remains unknown is, if emotional anticipation produces actual behavioural benefits, such as enhanced memory performance. At present, well-controlled studies on the role of anticipation in explaining EEM are scarce. As a first step towards the exploration of this phenomenon, the current experiment was conducted to investigate a simple and straightforward question: does anticipation modulate emotional memory at the behavioural level? If so, then exactly what sort of anticipation influences emotional memory, and in what way?

Expectancy is a construct closely related to anticipation. Some studies have highlighted the role of expectancy in memory formation and have illustrated that the mere expectation of some neutral (Bollinger, Rubens, Zanto, & Gazzaley, 2010) or unpleasant event enhances memory for it (Otten & Rugg, 2001). In imaging studies, increased activity was found in the amygdala and the hippocampus, both of which are brain regions known for emotional memory formation during the anticipation of emotional events (Nitschke et al., 2006b; Nitschke et al., 2009). These conclusions were based on studies in clinical populations with Generalized Anxiety Disorder (GAD) (Friedman, Thayer & Borkovec, 2000; Nitschke et al., 2009; Schaus et al., 2007). However, imaging studies conducted using healthy adults have found that greater activity in the amygdala and hippocampus is linked to the immediate recognition memory (Cahill, et al., 1996; Mackiewicz, et al., 2006).

In ERP literature, anticipation has been studied using the cueing paradigm, i.e., S1-S2. S1 is usually a cue stimulus which indicates a forthcoming stimulus S2 (e.g. picture). When the interval between the S1 and the S2 is long (e.g.4000ms), a waves form is typically formed associated with cue properties called Contingent Negative Variation (CNV). Just a few hundred milliseconds before the onset of S2 another waveform is observed called Stimulus Negative Variation (SPN). A detailed description of these waveforms and its relation to memory will be discussed in the subsequent ERP chapters. This chapter will address the behavioural findings of these ERP and fMRI studies because the purpose of this study is to investigate the behavioural outcome of the anticipation by manipulating different cues. The majority of available studies have focused on emotional anticipation using emotional images. However, very limited number of studies have focused on how emotional anticipation is related to memory formation. Two main theoretical accounts have been put forth as possible explanations for the mechanisms behind memory formation Pre-stimulus Dm effect at anticipatory phase. In an fMRI study, Mackiewicz et al. (2006) found significant memory effects for high-arousal emotionally negative images and explained the findings in the light of the modulation hypothesis of EEM. According to the modulation hypothesis, the amygdala engages the adrenergic [KN1] and cortisol stress-hormone systems that interact to promote memory storage in the cortex (see Chapter 1 for details). The same system is activated when aversive events are anticipated. In contrast to the modulation explanation of the Ps-Dm effect, the ERP study by Galli et al. (2011) explained the mechanism of the Ps-Dm effect at the anticipatory phase in evolutionary terms — that is, mental readiness or preparation for the upcoming negative event leads to memory formation. While these findings are illuminating and provide different explanations for the Ps-Dm effect found at anticipatory phase. Therefore, the present investigation is novel in that it focused on exploring whether or not anticipation benefits memory at the *behavioural* level.

The major issue with these studies is that they did not manipulate different cue type. The cue used in these studies were all informative providing very specific information about the S2. But the question arises, as to what happens to emotional memory when the cues provide less information or no information at all about the S2? There are few dispersing pieces of evidence that if the cues lack in information, even then it affects memory related components at neural level (Bem, 2011; Julia A Mossbridge et al., 2014b; Yick et al., 2015). Does it happen at a behavioural level also, is another specific question in this study? This aspect will be targeted in the ERP studies reported next in chapters. Here the focus is behavioural correlates of memory formation under Non-Informative and No Cue conditions. Task switching studies have frequently manipulated the informative content of the cues and revealed a relative independence of general task preparation and specific task activation (Finke, Escera, & Barcel, 2012). Informative cue contains specific task related information while that is not the case in non-informative trials. These two processes of general task preparation (non-informative cues) and specific goal activation (informative cues) engage common and distinct areas of prefrontal cortex depending on the information (Finke et al., 2012).It is unknown if similar or distinct mechanisms work behind memory formation under varying levels of information about emotional events. In sum, with regards to emotional anticipation and memory formation it is understudied area and needs systematic investigations.

In addition to the informative content of the cue, manipulation of the presence and absence of the cue becomes another important factor due to the use of emotional content in the paradigm.

There is evidence that presence of predictive cues enhances performance; it increases speed and accuracy of stimulus detection and discrimination (Bollinger et al., 2010; Gazzaley & Nobre, 2012). Informative cues lead to adaptation and decreased brain activations; reduced subjective experience of pain and the pain related brain activations in response to information about the stimuli as reported in few studies (Koyama, et al., 2005; Onoda, et al., 2006, 2007). In contrast, the absence of information about the impending aversive stimuli might enhance emotional arousal due to uncertainty and anxiety about the future upcoming event (Catena et al., 2012a; Sarinopoulos et al., 2010a). A study found larger P2 amplitude in the absence of the cues in female participants; P2 amplitude indicated selective attention to the trials where participants were unable to anticipate valence of the pictures (Jin et al., 2013; Peng et al., 2012). Startle amplitude for the unpredictable stimuli valence were stronger than the predictable stimuli (Grillon, 2008; Schmitz et al., 2011).

4.2.1 Anticipation and retention interval

Previous studies have obtained Ps-Dm effects for shorter (Galli, Wolpe, et al., 2011; Mackiewicz et al., 2006b) as well as for longer retention interval (Galli, Griffiths, & Otten, 2014). Retention interval is the time between study and memory test ranging from seconds to minutes or hours. In Recognition memory tasks, the effects of emotion on recognition performance tend to be robust and stable if long study-test intervals are used (Payne & Kensinger, 2010; Sharot et al., 2008). It is assumed that emotion-related hormones and neurotransmitter are responsible for the delayed effects of emotional content on recognition memory (McGaugh, 2004). Participants' recognition memory was tested after a retention interval of 24 hours in the current study and all the studies reported in the subsequent chapters.

4.2.2 Anticipation and remember-know paradigm

In most of the Ps-Dm effect studies, researchers have employed Remember/Know paradigm to test recognition memory performance. The behavioural findings of the previous few studies on Ps-Dm effect have found a greater influence of emotion on the accuracy of Remember judgments than Know judgments and overall recognition memory accuracy. In this project Remember/know paradigm has been used to assess memory performance. R-judgments, also known as recollection and K-judgments also named as familiarity are assumed as sub-components of recognition memory according to the Dual process model of memory. By definition, recollection/R-Judgment is the retrieval of an event that is accompanied by detailed and associated information of the event such as time and location. In contrast, familiarity/K-judgment is the feeling that an event has been experienced before. However, its details are missing. Dual process theory assumes these two memory components are distinct as they recruit different brain regions (Bowles et al., 2007, 2010; Squire et al., 2007). There is controversy on this issues as Signal Detection Theory theory criticizes familiarity and recollection as two different subcategories of memory. Rather it posits that recognition decisions are based on the strength of memory signal that ranges from weak to strong on a single continuum and engage same brain regions (Curran et al., 2006; Mandler, 2008; Rutishauser et al., 2008). Despite this controversy, the majority of studies in neuroscience heavily rely on Dual-process model.

Remember and Know responses are a way of splitting "old" responses into two groups: one in which participants presumably recollect the items and one in which they presumably feel familiarity with the item without necessarily recollecting it. This assumption follows from the fact that participants can only produce one type of response during the experiment: The participant have to choose either "Remember" or "Know". However, it is possible that in some cases people experience both processes for a given item. Recollection and familiarity may be independent processes ("you can have one without the other, but they can also co-occur"), but it is not necessarily the case that they are exclusive ("if you have one then you cannot have the other"). In this case, a formula is used to correct the K responses. The K correction tries to correct for this exclusivity assumption that results from the way the experiment is set up (i.e., asking people to say only R or only K). Yonelinas and Jacoby (1995) introduced the formula for K-correction, given below:

$$K\text{-}\textit{correction} = K/(1-R)$$

The idea of applying the correction to Know responses is that if the two processes are independent there will be some proportion of items that are both familiar and recollected (a possibility not allowed by the exclusivity assumption. To determine the probability that an item is familiar (F), one must divide the proportion of "know" responses (K) by the proportion the subject has to make a "know" response (Yonelina & Jacoby, 1995).

4.2.3 Rationale of current experiment

In the current experiment, emotionally negative and neutral images were presented under three different anticipatory conditions: the Informative cue condition, the Non-Informative cue condition, and the No-Cue condition. The Informative Cue (Info-Cue) condition provided full information about the valence of the upcoming picture. This condition allowed activation of a preparatory process in contrast to the Non-Informative Cue (Non-Info) condition, in which the cue did not include particular information about the valence of pictures. In the No-Cue condition, pictures were displayed without any cue. Therefore, the possibility of the preparation of picture valence does not exist. It is predicted that uncertainty about the valence of upcoming emotional images and lack of opportunity for preparation to perceive emotional images might produce an arousal state and hence an emotional context which might promote the formation of long-lasting memories (Jin, et al., 2013; Peng, De Beuckelaer, Yuan & Zhou, 2012). Therefore, a memory advantage for No-Cue cue condition is predicted. The prediction regarding the Informative cue condition is made for replication purposes. In an everyday situation, many events happen unexpectedly without cues and investigation into the ability to detect unanticipated dangerous event would be vital for adapting and rapidly changing the environment.

4.2.4 Study objectives

Following research questions are set for the current study:

(i) Does specific information about the emotional pictures (Informative cue) lead to enhanced memory formation compared to the conditions in where specific information lacks (Non-Informative cue)?

(ii) Does the presence of cues modulate emotional memory greatly in contrast to the absence of cue (No-Cue condition)?

(iii) Does the absence of cues create an emotional context to better encode emotional stimuli under a No-Cue condition?

4.3 Method

Thirty-six healthy female participants (mean age = 20.31 years, SD = 3.4 years) were recruited from an undergraduate participant pool. All participants were right-handed and reported no history of psychiatric or neurological illness. All had normal or corrected-to-normal vision. The experiment was approved by the Durham University Department of Psychology's Ethics Sub-committee, and all experiments were carried out by the Declaration of Helsinki, with the understanding that participants could withdraw at any time. Each participant completed Depression, Anxiety, and Stress Scales (DASS: appendix K), used as a measure of negative emotional states (Lovibond & Lovibond, 1995). All participants were found to be in the normal range of scores on all subscales (Depression, X = 2.81, SD= 3.14; Anxiety, X = 3.06, SD= 3.77, and Stress, X= 8.03, SD = 6.12) of DASS. The participants also signed informed consent forms before their participation in the experiment.

4.3.1 Design

The experiment used a within-subject experimental design. Three levels of anticipation were manipulated: Informative Cue, Non-Informative Cue, and No Cue conditions. In the Informative Cue condition, participants were provided with specific information about the valence (negative or neutral) of the ensuing pictures. In the Non-Informative Cue condition, participants were unaware of the valence of the forthcoming pictures; and lastly, No Cue condition pictures were presented without any cues.

4.3.2 Stimuli and Materials

Two types of stimuli were used in the experiment: cue stimuli and picture stimuli. For the Informative Cue condition, upper case letters X and O were used as cues for negative and neutral pictures, respectively. X and O were counterbalanced. The letter 'Z' was used for the Non-Informative Cue condition, and was not informative of the valence of the upcoming picture. In the No-Cue condition, a blank screen appeared and then the picture was presented. Participants had to rate the valence of each picture using the Self-Assessment Manikin (SAM) rating scale. They were instructed to prepare themselves for the picture mentally prior to the cue being displayed. The cues were always congruent with the picture. Moreover, participants were not informed about the subsequent memory test.

For picture stimuli, a total of 558 pictures were selected from the International Affective Picture Systems (IAPS) and sorted as follows: 279 negative and 279 neutral pictures (Lang, 2005). Negative and neutral picture sets were carefully matched to avoid confounds due to the presence of specific types of pictures, such as the presence of a human face, a human body, and animal and object pictures in each valence category. The selected picture sets differed significantly on valence $t(556) = 46.37$, $p < .001$ and arousal ratings $t(556) = 39.50$, $p < .001$, according to the normative rating given in the IAPS manual. Some of the negative and neutral pictures were selected from Google Images so that the number of pictures for each condition in the experiment was matched. The valence of the negative and neutral pictures varied on average between 1.11-3.44 and 2.5-4.00 respectively on a scale of 1-9, while arousal pictures varied on average between 2.11-4.61 for negative pictures and 1.14-2.89 for neutral pictures (see Appendix H for a complete list of pictures with valence and arousal ratings). The Same set of pictures has been used in the studies reported in chapter 5 and 6 with a little variation in the number of pictures in each study. It was due to the adjustment of an equal number of negative and neutral pictures in each block according to the number of conditions used.

Out of the selected 279 negative and 279 neutral pictures, 198 pictures were designated as old, and 81 as new for each valence category. An equal number of negative and neutral pictures were presented. Sixty six (66) pictures from each valence category were presented during each condition. The study phase consisted of 396 trials, split into eight blocks, with a short rest period after each block. To avoid any memory bias in the study phase, the negative and neutral pictures were presented with the constraint that no more than two consecutive trials presented the same stimulus valence. The old/new status of the negative and neutral pictures, cue type, trials, and block order was counterbalanced across participants.

The test phase consisted of 558 randomly allocated items, divided into two groups: 396 old pictures and 162 new pictures (81 negative and 81 neutral). All pictures were presented in eight blocks. All blocks in the test phase contained an equal number of negative and neutral pictures. The trials in the test phase were presented in random order without any constraints imposed on them. Therefore, in the test phase, only the order of the blocks was counterbalanced (in old/new, informative, negative/informative, and neutral/non-informative conditions). In the test phase, the cues remained on the screen before the presentation of each picture, to keep the stimulus and block presentation parameter constant across study and memory retrieval phases.

4.3.3 Procedure

Participants sat in a sound-proofed EEG lab in an armchair at approximately 70 cm away from a 19 CRT computer screen used to display the stimuli. They went through the instruction sheets and signed the consent form (see Appendix I & J, respectively). During instruction, they were told what each cue stands for and which type of picture it represented. To clarify their understanding, and to familiarise them with the experimental procedure, they completed a practice phase consisting of 12 trials. The experiment was presented using E-prime 2.0 (Psychology Software Tools, Pittsburgh, PA), and pictures were displayed in the centre of the screen on a white background.

4.3.3.1 Study /Encoding Phase 1

The study phase began with a fixation point (+) which appeared at 0ms - 1000ms. The cue then appeared for 1000ms and was replaced by another fixation sign for 2000ms. The picture was then presented for 1000ms. After the picture display, participants rated the valence of pictures using SAM. The task of rating pictures was self-paced. A blank screen was presented in the no cue trials (see figure 4.1). Inter trial intervals varied randomly from 4000ms to 5000ms.

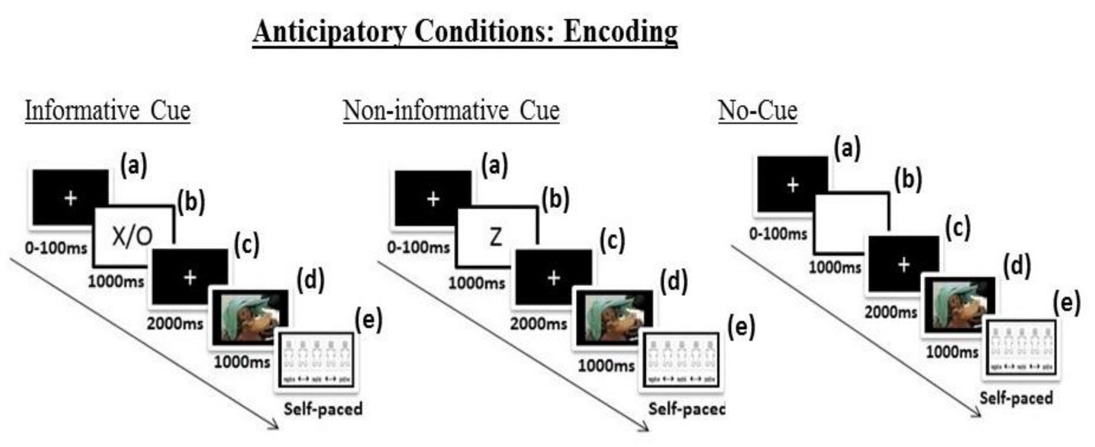


Figure 4.1: A schematic illustration of a trial structure for three anticipatory conditions. Informative cues represented by X = negative and O = neutral, Non-Informative cue represented by Z and No cue slide is blank presented during encoding phase. (a) the trial started with first fixation sign for 100ms followed by (b) Cue type (for informative and non-informative cues X/O/Z respectively and for No-cue a blank screen) remained on the screen for 1000ms after that (c) Another fixation appeared and remained on the screen for 2000ms. This was the anticipatory phase consisted of a total of 3000ms (d) Pictures were displayed for 1000ms (e) Self-Assessment Manikin (SAM) picture rating task was presented in the last slide which was self-paced.

4.3.3.2 Test/ Retrieval Phase

A memory test followed the study phase by an interval of 24 hours for better consolidation of emotional memory. It was an incidental memory test in which participants were not aware that a memory test would follow the next day. Participants were presented with all the pictures they viewed in the study phase (old pictures), randomly mixed with new ones. The recognition memory was tested by incorporating the confidence rating of the old/new items (6-point bipolar scale, ranges from 1= absolutely sure the picture is new to 6 =

absolutely sure the picture is old), followed by a Remember/Know judgments in the case of an “old” response.

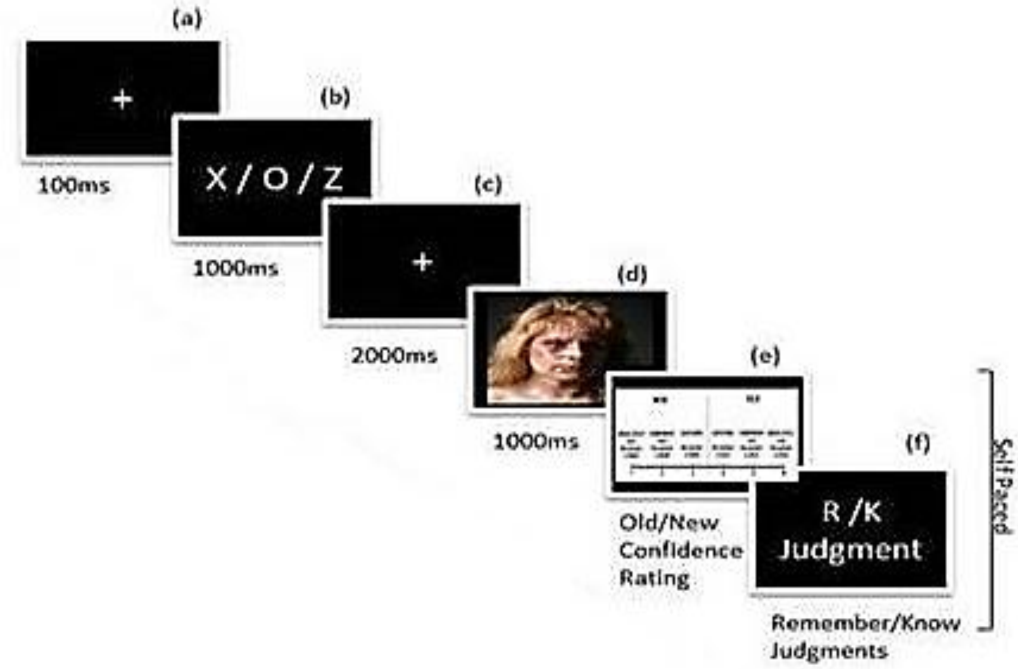


Figure 4.2: An illustration of the trial structure for test/retrieval phase.
A single test trial started with (a) a fixation sign which last for 100ms on the screen and then a (b) cue was presented similar to the study phase for 1000ms (c) again a fixation sign displayed for 2000ms time interval (d) picture was presented for 1000ms (e) old/new judgment and confidence rating scale was presented which was followed by (f) a Remember (R) Know (K) judgment for the recognized pictures. The confidence rating scale and remembered/know judgement task was self-paced and required no quick judgment by the participants.

Participants responded by pressing one of the two response keys specified for (R/K) judgment on the keyboard, with the right index or middle finger, respectively. A ‘new’ response was also followed by pressing the two specific keys (left/right, not significant to the experiment), to equate it with the motor activity associated with the ‘old’ response. Prior to the test phase, participants were presented with the practice block to fully comprehend R/K judgment task. Recognition memory responses were self-paced.

4.3.4 Statistical Analysis

The methods and analysis used in this behavioural study are same as conducted for the behavioural data in the subsequent ERP studies reported through Chapter 5-7. Memory data is analysed using standard measures used in the majority of the EEM studies. Abbreviation used are as follows: Hit rates (HR) is the proportion of “old” responses given to old pictures which participants recognised correctly. Hit rate (HR) data was further sorted into R-hits and K-hits which are the proportion of R and K judgements given to old responses respectively. K-corrected was also obtained using the formula $K_{corr}=(K/(1-R)$ to get an independent measure of K responses. False alarm (FA) is the proportion of "old" responses to "New" pictures. New pictures were the ones not shown to participants in the study phase. Data was analysed in two ways: One, Recognition memory data based on the proportions of Hit rates, False alarm, R-hits, K-hits and K-corrected, were analysed without checking for accuracy to see the trend of the data and summarised in the table. Further, the accuracy of recognition judgements was established with discrimination index called Pr-index. *Pr* is the difference between the hit rates and false alarm $Pr = (HR-FA)$. Pr-index is usually conducted to find out how accurately subjects recognized an item as old or as new using the high threshold model (Snodgrass & Corwin, 1988). Pr-index was calculated for HR as well as for R-hits to see the difference in overall memory accuracy and R-judgments accuracy.

A 3 (Cue conditions: Informative, No-Cue, Non-Informative) × 2 (Valence: Negative, Neutral) repeated measures ANOVA was conducted for all the analyses in this study. The significant two-way interaction was followed up with test of simple-simple main effects. This is analogous to follow up a statistically significant two-way interaction in a two-way repeated measures ANOVA with simple main effects. However, the same naming convention applies here as it did with the simple two-way interactions, with the simple main effects of the simple two-way interaction referred to as simple-simple main effects. Some form of correction is applied when testing multiple simple two-way interactions. Bonferroni adjustment is applied to the level at which result is statistically significant in this study. It is done by dividing the current level of statistical significance at (i.e., $p < .05$) by the number of simple two-way interactions (i.e., 2). Thus, a simple two-way interaction is statistically significant when $p < .025$ (i.e., $p < .05/2$) (Keppel & Wickens, 2004; Kesselman, Rogan, Medoza, & Breen, 1980; Kirk, 2013; Maxwell & Delaney, 2004; Weisberg, 2014).

4.4 Results

A two-way repeated measures ANOVA was conducted to determine the effects of cue type and, valence (picture type) on memory performance. There were no outliers after excluding data from four participants, and memory scores were normally distributed ($p > .05$), as assessed by Shapiro-Wilk's test of normality. All necessary tests of sphericity showed that the assumption was met, as assessed by Mauchly's test of sphericity ($p > .05$).

4.4.1 Recognition data; Hit-rates, R-hits, K-hits, K-corr-hits and False Alarm

A 3(Cue conditions: Informative, No-Cue, Non-Informative) × 2 (Valence: Negative, Neutral) repeated measures ANOVA on overall memory performance, i.e., Hit rates (R hits + K-hits = HR) revealed no main effect of Valence, Cue condition and no Cue × Valence interaction respectively, $Fs < 1.52$, $Ps > .22$. Data were further analysed separately for R-hits and K-corrected hits rates. ANOVA for R-hits revealed a significant main effect of Valence, $F (1, 31) = 27.91$, $p = .001$, $\eta 2p = .474$. Negative pictures were recollected more than neutral pictures (MR-hits= .51, .40; SEs = .033, .037, respectively). The main effect of Cue condition and the Cue × Valence interaction were not significant, $Fs < .46$, $Ps > .63$. For corrected K-hits, no main effects for Cue and Valence and Cue × Valence interaction were significant, $Fs < .73$, $Ps > .06$.

For false alarm data, the main effect of Valence was non-significant, $F (1, 31) = 1.44$, $p = .238$, $\eta 2p = .045$, however for Cue condition it was significant, $F (1, 31) = 4.11$, $p = .021$, $\eta 2p = .117$ Pairwise comparisons showed that FA rate was higher for No-Cue condition (MFA = .14 , SEs = .012) compared to Non-Informative cue condition (MFA = .12, SEs = .014) and Informative Cue condition (MFA =.11, SEs = .011). Cue × Valence interaction was significant, $F (2, 62) = 8.46$, $p = .001$, $\eta 2p = .214$. To elucidate this interaction, data were separated by cue conditions. Simple main effects analysis revealed that for No-Cue condition false alarm rate difference between the negative and neutral pictures was significant, $F (1, 31) = 12.93$, $p = .001$, $\eta 2p = .294$. It was higher for negative compared to neutral pictures (MFA = .17, .11, SEs = .013, .015, respectively). FA rate was not significant for Informative, $F (1, 31) = 3.68$, $p = .064$, $\eta 2p = .106$ as well as for Non-Informative cue condition, $F (2, 62) = 1.22$, $p = .276$, $\eta 2p = .038$.

For completeness purpose, recognition data was also split by valence categories. HR, R-hits, K-hits and FA analysis was conducted separately for negative and neutral pictures. Simple main effects analysis of the Hit-rates (HR) and R-hits and K-hits for negative pictures revealed a non-significant main effect of cue condition, $F (2, 62) = 1.98$, $p = .15$, $\eta 2p = .060$; $F (2, 62) = .02$, $p = .98$, $\eta 2p = .001$; $F (2, 62) = .2.31$, $p = .107$, $\eta 2p = .070$ respectively. However, the only significant main effect was for false alarm, $F (2, 62) = .14.40$, $p = .001$, $\eta 2p = .317$. Pairwise comparison of cue conditions revealed that on average, FA rate was significantly higher for No-Cue condition (M = .17, SE = .013) than Informative cue (M = .10, SE = .014) and Non-Informative Cue (M = .13, SE = .017). Only the Informative/No-Cue and No-Cue/Non-Informative cue conditions were statistically significant ($p < .05$). Informative/Non-Informative appeared to be equal with regards to FA rate. For neutral pictures, simple main effects analysis of HR, R-hits, K-hits and FA data revealed no significant differences across cue conditions for HR, R-hits and K-hits (Fs < .78, Ps > .05). Main effect of false alarm rate was also not significant, F (2, 62) = 1.07, p = .35, $\eta 2p$ = .033.

Recognition memory performance under three cue conditions is summarized in Table 4.1.

Table 4.1: **Proportions of recognition memory performance and its sub-components as a function of cue condition, and picture valence**

Picture Type		**Negative**		**Neutral**	
Cues	Memory status	*M*	*SD*	*M*	*SD*
Informative	HR	.81	.09	.77	.13
	R-hits	.52	.19	.39	.22
	K-hits	.29	.15	.38	.17
	FA	.10	.08	.14	.09
No-Cue	HR	.81	.10	.78	.14
	R-hits	.52	.19	.40	.21
	K-hits	.30	.14	.38	.17
	FA	.17	.07	.12	.08
Non-Informative	HR	.83	.09	.79	.14
	R-hits	.52	.19	.41	.21
	K-hits	.31	.15	.38	.16
	FA	.13	.09	.12	.08

Note : The proportion of Hit rates is the sum of the proportions of "Remember (R-hits)" and "Know" (K-hits) responses. The data, "K-hits" corresponds to the uncorrected know responses. The data for the corrected know responses Kcorr = K/(1-R) is given in the text. False alarm rate is proportions of old responses to new pictures.

4.4.2 Accuracy of Recognition Judgments

The analysis reported above tested the recognition memory performance. However, the accuracy of recognition judgments were measured with discrimination index called Pr (e.g. the proportion of the hit minus the proportion of false alarm (Snodgrass & Corwin, 1988). The results with Pr combines hits and false alarm rates into a single measure. This section reports the Pr-Index for overall recognition memory accuracy (Pr_Hit-rates) as well as for R-judgment (Pr-R_{hits}) separately. The purpose is to show more precisely the differential impact of cue manipulation on the accuracy of memory for overall memory judgments Hit-rates and R-hits judgment.

4.4.3 Pr-Index for overall memory accuracy (HR)

A 3(Cue conditions: Informative, No - Cue, Non-Informative) × 2 (Valence: Negative, Neutral) repeated measures ANOVA on Hit Rates (HR) revealed a significant interaction for

Cue × Valence, $F(2, 62) = 4.25$, $p = .019$, $\eta^2p = .121$. Using simple effect analysis, data were separated by Cue conditions revealed a significant difference between the recognition accuracy of the negative and neutral picture for Informative Cues only, $F(2, 62) = 7.20$, $p = .01$, $\eta^2p = .189$, but not No-Cue and Non-Informative cue conditions ($Fs < 1.19$, $Ps > .28$). Simple pairwise comparisons were run between the negative and neutral pictures for memory accuracy for the informative cue only. Data were mean ± standard error unless otherwise stated. A Bonferroni adjustment was applied. There was a statistically significant difference between the negative, and neutral pictures that is negative pictures were recognized with greater accuracy than neutral pictures (MPr = .70, .63, SEs = .019, .024, respectively). Main effect of the Cue condition, $F(2, 62) = 2.98$, $p = .06$, $\eta^2p = .088$ and Valence was non-significant $F(2, 62) = 1.77$, $p = .193$, $\eta^2p = .054$ (see figure 4.3)

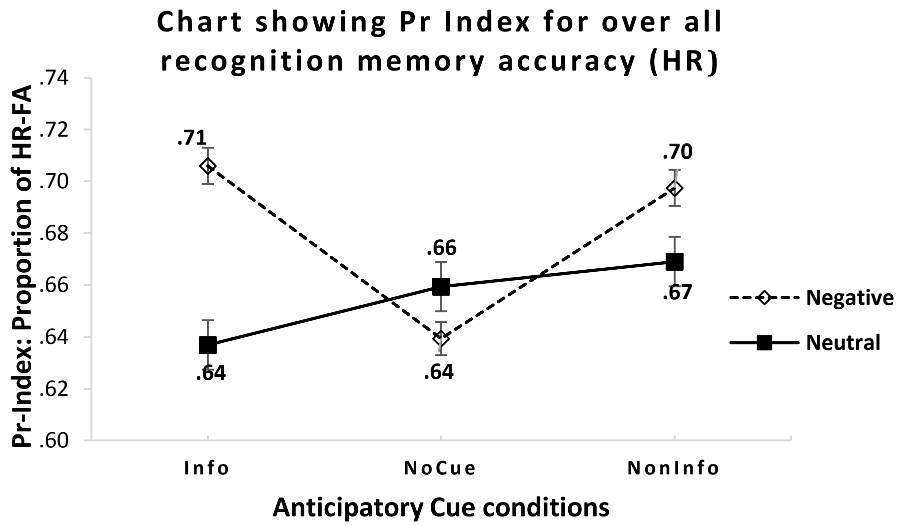


Figure 4.3: Pr-Index for overall memory accuracy: Hit Rates scores (HR).

HR scores combine R-hits and K-hits into one measure. Pr-index for HR was obtained by subtracting the proportion of HR from the proportion of false alarm, Pr ($P_{HR} - P_{FA}$). The figure showed that overall recognition memory was accurate for those negative pictures presented with the Informative cue. Emotional memory was non-significant for the pictures presented under Non-Informative and No-cue conditions

Recognition memory accuracy index for negative and neutral pictures was separately analysed for three cue conditions. Simple main effect analysis revealed a significant main effect of negative pictures, $F(2, 62) = 8.36$, $p = .001$, $\eta^2p = .212$ but non-significant for neutral pictures. Further pairwise comparisons for negative pictures indicated higher mean scores under informative and Non-informative cues than No-Cue condition (MPr = .71, .70, .64; SEs = .019, .022, .021, p = .001, .008, respectively. These findings indicated that accuracy of memory for negative pictures was higher for informative as well as for Non-informative cue condition than No-Cue condition (see figure 4.4).

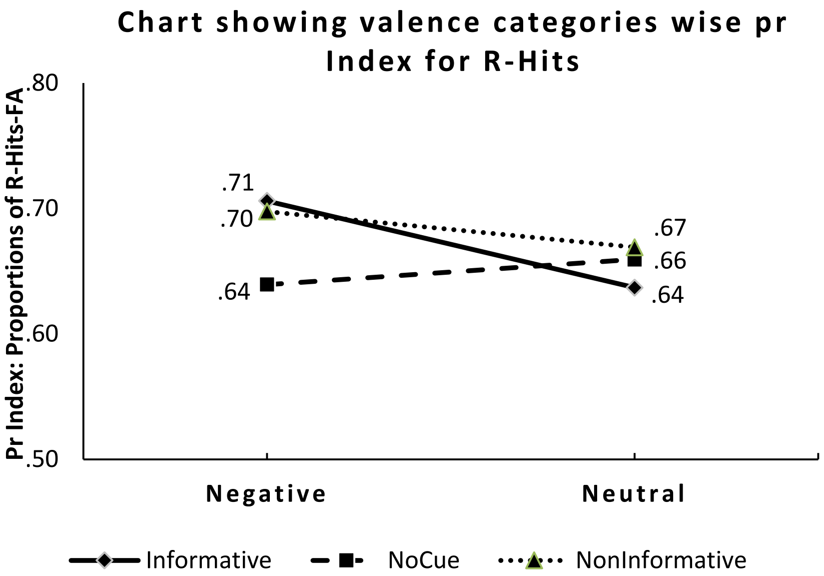


Figure 4.4: Valence wise Pr-Index for recognition memory scores (Hits rates)

The figure shows that negative pictures were recognized with greater accuracy under Informative as well as Non-Informative cue condition as compared to No-Cue conditions.

4.4.4 Pr-Index for R-judgments (R-hits)

The aforementioned *Pr* analysis was conducted using Hit Rates (HR) which combines data from Remembered (R) and Know (K) judgments. Additionally, Pr-Index analysis was calculated for Remembered (R) judgments only. It was done to see the accuracy of R judgements because only R responses have been considered for anticipatory phase in the in the Event-Related Potential (ERP) studies literature on pre-stimulus Dm effect. A 3(Cue conditions: Informative, No-Cue, Non-Informative) × 2 (Valence: Negative, Neutral) repeated measures ANOVA on (R) judgments revealed a significant Interaction for Cue × Valence, $F(2, 62) = 4.93$, $p = .01$, $\eta 2p = .137$. Cue wise subsidiary analysis revealed a significant main effect of valence for Informative Cues, $F(1, 31) = 23.78$, $p = .001$, $\eta 2p = .434$. as well as for Non-Informative cues, $F(1, 31) = 12.02$, $p = .001$, $\eta 2p = .282$. Simple pairwise comparisons were run between the negative and neutral pictures for Recollection accuracy (Pr-R) for both Informative and Non-informative cues. A Bonferroni adjustment was applied here, and data were mean ± standard error unless otherwise stated. For Informative cues, the pairwise analysis yielded higher Pr recollection scores for negative as compared to neutral pictures (MPr = .41, .25, SEs = .036, .040, respectively). For Non-Informative cues, the same trend as Informative cue was found that accuracy of negative R responses was higher than neutral (MPr = .38, .29, SEs = .037, .041, respectively). For No-Cue condition simple effects were non-significant, $F(1, 31) = 3.83$, $p = .06$, $\eta^2p = .110$ (see figure 4.5).

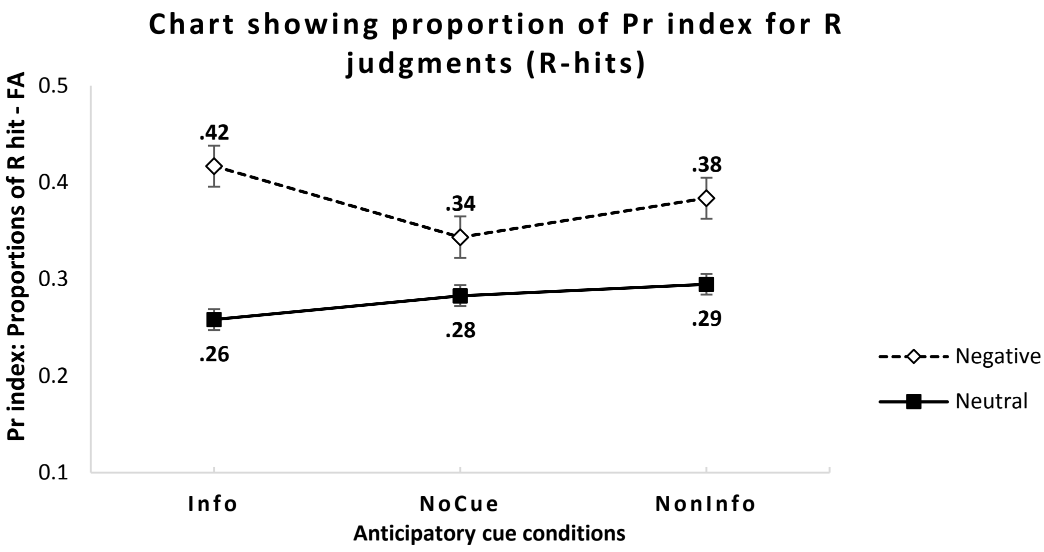


Figure 4.5: Cue wise Pr-Index for R judgements/ R-hits.

Pr Index for R-hits was obtained by subtracting the proportion of R-hit from the proportion of false alarm, Pr (P-R-hit Rates – P- FA). The figure shows that recollection memory was accurate for negative pictures as compared to neutral under Informative and Non-Informative cue condition only. The No-cue condition could not yield significant differences.

Valence wise subsidiary simple effect analysis revealed a significant difference for negative pictures recognized under three cue conditions, $F(2,62) = 6.29$, $p = .003$, $\eta^2p = .169$. Pairwise comparison revealed that participants recollected more negative pictures in Informative cue condition (M= .41, SEs = .036, p = .01) than in other two cue conditions, No-Cue and Non-informative (M = .34, .38, SEs = .035, .037, p = .199, .206 respectively). However, difference between memory scores for neutral pictures for the cue conditions was non-significant, $F(2,62) = 1.43$, $p = .246$, $\eta^2p = .04$ (see figure 4.6)

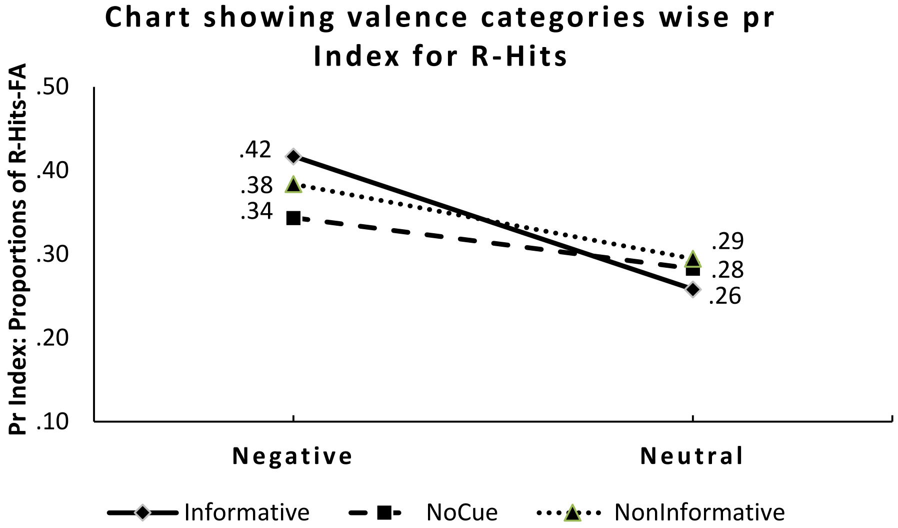


Figure 4.6: Valence wise Pr-Index for R judgements/ R-hits.

The figure shows that negative pictures were recollected accurately under Informative cue condition as compared to No-Cue and Non-Informative cue conditions.

In summary, these results indicate that the overall recognition memory accuracy was influenced when the participants are aware of the type of the upcoming picture (informative cue and negative pictures). However, when the (R) judgement was considered on its own, negative pictures were remembered significantly more but only in the informative and non-informative condition.

4.5 Discussion

The main objective of the current behavioural experiment is to investigate whether or not anticipation influences emotional memory formation. Central questions of interest included: Does preparation using informative cues lead to enhanced memory formation compared to the other two conditions (non-informative cues vs. no cue) in which opportunity for preparation was not available? Does the presence of cues matter or not? Do cues cause an arousal effect that leads to enhanced memory for emotional stimuli under non-anticipatory (No-Cue) conditions?

The current behavioural study revealed two important findings: One; it suggests that presence of cues is a significant factor for memory formation and enhancement. In comparison to Informative and Non-Informative cue conditions in which cues were present on the screen, memory was impaired in the condition where the cue was absent. This pattern of findings suggests that somehow memory formation is related to the presence of cue, no matter they are informative or non-informative. The presence of cue represents some expectations which were lacking in No-Cue condition. Expectation guides attention and facilitate memory formation (Gazzaley & Nobre, 2012). Several studies have found that presence of predictive cues enhance perceptual performance and improve the accuracy of stimulus detection as well as the speed of the response (Posner, 1980). Presence of predictive cues selectively guide attention to a particular object (Esterman & Yantis, 2010) location (Kastner, Pinsk, De Weerd, Desimone, & Ungerleider, 1999) and the properties of stimulus (Chawla, Rees, & Friston, 1999; Giesbrecht, Weissman, Woldorff, & Mangun, 2006). Some studies reported that cues facilitate the transfer of mental representation formed by the type of the cue into the working memory (Griffin & Nobre, 2003; Palmer, 1990).

Another hypothesis tested for No-Cue condition was that emotional memory might improve due to uncertainty in this condition. No-Cue condition contains uncertainty about the upcoming picture valence and about the time of its occurrence. Some previous studies showed that individuals encode emotional stimuli and events better in the emotional context and arousal (Jin et al., 2013; Peng et al., 2012). Contrary to the predictions, no emotional memory advantage was found for No-Cue condition over other two conditions. This result excludes the possibility of uncertainty and emotional context's role in enhanced emotional memory.

No-Cue data also revealed a higher false alarm rate in this condition compared to the other two conditions where the cues were presented. The lower accuracy of remembered pictures under the No-Cue condition seems mainly driven by the higher false alarm rate for this condition in comparison to Informative and Non-Informative cue condition. The pattern of results in the No-Cue condition is further important because all the previous studies on the role of informative cues have been conducted without a control condition. Non-informative and No-Cue conditions served as a control against which the preparatory process hypothesis can be assessed.

The second most important finding is that emotional memory for negative pictures improved compared to neutral pictures not only under Informative cue condition but also under Non-Informative cue condition. In Non-Informative cue condition, the participants were unaware of the valence of the upcoming picture and hence, could not get themselves prepare to attend to the particular images. What accounted for theses results in Non-Informative cue condition? One possible explanation may be that that information the cues provide does not matter and in both cases a general preparation in the presence of some sort of cues lead to memory formation. To the best of knowledge, research and literature on the memory advantages for Non-Informative cue condition is in infancy. It is the first behavioural study of its sort which combined and compared three different cues for a test of emotional memory enhancement. Moreover, no ERP study so far has tested emotional memory formation for Non-Information cue in contrast with the informative cue. Therefore, the supporting studies are scarce. Most of the explanation available on memory advantage for Non-informative cue comes from two recent review articles that have tried to pen down the explanation for such results (Mossbridge et al., 2014; Mossbridge, Tressoldi, & Utts, 2012a). Mossbridge, et al. (2012) conducted a meta-analysis of 26 studies and found that human physiology can detect stimuli occurring in 1-10second in the future in the absence of systematic information about the stimulus which occurs randomly. He named this phenomenon as an unexplained anticipatory activity that reflects the reverse direction of post-stimulus physiological activity. Later, in a recent review paper on this issue in 2014, he further referred it to as 'predictive anticipatory activity' which because it is predictive of randomly selected future events in the absence of cues and it has its basis in physiological activity. He tried to provide a more scientific definition of the pre-stimulus activity in the absence of informative cues in contrast to Bem, et al. (2011) who called this activity as pre-cognition and suggested that the perception of a future event may influence memory in the present.

Few task switching studies have compared informative and partially informative cues on the role of inhibition in task switching. These studies have not found any behavioral benefit of partially informative cues compared to Informative cues. However, ERP studies have found an early cue related positivity elicited by both fully and partially informative cues and suggest that both types of cues trigger an anticipation related component of the task set reconfiguration (Karayanidis et al., 2009; Nicholson, Karayanidis, Davies, & Michie, 2006). Findings from the task-switch paradigm can not be generalized to the emotional memory formation in response to the cue, however, it provides a glimpse into what happened neural level which may account for these behavioural findings. These results are intriguing as they provide the first behavioural evidence for the enhanced memory for emotionally negative pictures when the participants were not given accurate information as what to they had to encode. The finding is encouraging as it provides the initial evidence in the full comprehension of available literature on the role of anticipation in enhancing emotional memory. The greatest motivation for designing a research project on anticipation and emotional memory came from the similar findings in responses to a fixation sign found during exploratory analysis of a study on emotional memory (Yick et al., 2015). The findings of the current study and the one by Yick et al. (2015) contrast with the findings obtained with Informative cue (Galli, Wolpe, et al., 2011). Researchers argued that informative cues facilitate preparatory process before the event happen and whereby, facilitate memory encoding preferentially for emotional images. Since Yick et al. (2015) found these results in response to a fixation. Therefore, they speculated it might be caused by Random Fluctuation in attention. Since the studies above found an emotional memory effect for the neural activity in the anticipatory phase, while the current study found behavioural evidence, therefore the findings are generalizable only to the behavioural studies. From the current behavioural findings, it is not unknown if some common or distinct mechanism work responsible for memory advantage under both conditions. Three studies reported in Chapter 5, 6, 7 have provided information on neural activity related to emotional memory investigated under these three cue conditions.

4.6 Conclusion

This study demonstrated that anticipatory cue conditions (both informative and non-informative improve emotional (negative) memory performance at the behavioural level. These results ward off the preparatory process explanation previously given for enhanced emotional memory under informed anticipation at the neural level. Enhanced emotional memory for Non-Informative cue conditions points towards the fact that there might be some other mechanism working behind the enhanced memory for both anticipatory cue conditions. However, it is yet to be explored if that potential mechanism is distinct or similar for both cue types. These findings also provide evidence that the presence of the cue is important for emotional memory advantage. The findings did not support the hypothesis that arousal might enhance attention and thereby memory for emotional stimuli under No-Cue conditions. In sum, the findings suggest that presence of cue matters more than the information content of the cues for the emotional memory formation.

4.7 Future Directions

It is the first study that focused on the role of anticipatory cues in the memory formation. Findings of this study are intriguing and provided several insights for the subsequent experiments, especially neural evidence to corroborate the behavioural findings. Dm effect is a neural phenomenon, to investigate the neural substrate of the emotional memory in the anticipatory phase; the next experiment focused on the neural correlates of emotional memory under Informative and No-Cue condition. Moreover, in the preceding ERP chapters, possible explanations for EEM effect for anticipatory cues have been discussed such as modulation hypothesis, random fluctuation in attention, pre-cognition and Predictive anticipatory activity.

Chapter 5: Pre-stimulus subsequent memory effects in absence and presence of cues

5.1 Overview

The previous chapter uncovered a behavioural effect for informative and non-informative cues but only for negative stimuli. The current event-related electroencephalogram (EEG/ERP) study examined the neurological basis of the role of anticipation in enhancing emotional memory by manipulating Informative cue (Info-Cue) and No-Cue conditions. Previously studies identified a Ps-Dm effect, an ERP component at the anticipation phase that is considered an indicator of encoding or memory formation (Galli, et al. 2011). However, this effect has been established without a controlled experimental condition. In the current study, the Informative cue was presented with a No-Cue condition to test if the presence or absence of an informative anticipatory cue matters at neural level? The informative cue condition served the purpose of replication while the No-Cue condition was a novel aspect of the study. Findings revealed that informative cues influenced memory formation during anticipatory phase but regardless of the valence of the pictures. No-Cue condition yielded non-significant difference for memory and valence.

5.2 Introduction

In everyday life, positive and negative events routinely occur, and they may do so with or without warning. For example, while someone with an upcoming birthday might expect to get that laptop they've been begging for, conversely a farmer's land may be hit by a destructive tornado without any signal. While the expectation of a positive or negative event can be emotionally arousing, so can being hit with an event unexpectedly. Thus, the question of interest is, in which case would a permanent trace of the event be left in memory: the one in which the individual was prepared, or the one that occurred without prior warning? In the present experiment, this matter is investigated using an electrophysiological approach. Specifically, the question of interest is whether or not anticipatory cues are important for a pre-stimulus difference due to memory (Ps-Dm) effect. If the presence of cues does, in fact, modulate the electrophysiological activity, then how do those cues interact with valence of pictures (negative/neutral) to modulate subsequent activity related to memory.?

The idea that emotions enhance memory of positive or negative events over neutral events is known as the emotion-enhanced memory (EEM) phenomenon (LaBar & Cabeza, 2006; Rimmele, Davachi, & Phelps, 2012). A number of studies so far have reliably found an index of emotional memory encoding, i.e., a Dm effect in neuroimaging (fMRI) (Cahill & McGaugh, 1998; Dolcos & Cabeza, 2002; Kensinger & Corkin, 2003; Pottage & Schaefer,

2012) and event -related potential (ERP) studies (Schaefer & Philippot, 2005; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008). In the ERP literature, the Dm effect is defined as a differential neural activity for remembered and forgotten items (Paller & Wagner, 2002). It includes an onset at approximately 400ms with a frontal topography. Notably, in all these studies, the Dm effect reflects the ERP activity after the exposure to the actual emotional event, such as the perception of pictures/ words.

A recent investigation into EEM reported a Dm effect prior to the presentation of emotional stimuli in response to anticipation (Galli et al., 2014; Galli, Bauch, & Gruber, 2011; Galli, Wolpe, et al., 2011). Leading researchers (Otten, Quayle, Akram, Ditewig, & Rugg, 2006), who first reported Pre-stimulus (Ps) Dm effects, proposed that the mere anticipation of something aversive might lead to amplitude differences for remembered versus forgotten items (Galli et al., 2011). The study reported a Ps-Dm effect only at the anticipatory phase, the activity in this phase corresponded to the cue presentation. Galli et al. (2011) attributed the Ps-Dm effect to the preparatory process at work, which facilitated encoding, thereby resulting in a strong emotional memory. To distinguish the cue-related Dm effect from the picture related Dm effect, pre-stimulus Dm effect will be reported as the "Pre-stimulus difference due to memory'' effect (Ps-Dm effect) throughout the thesis.

5.2.1 Preparatory process hypothesis

The anticipation of a threat or an unpleasant situation serves an adaptive function (Baumeister, Vohs, DeWall, & Zhang, 2007; Lorini, Piunti, Castelfranchi, Falcone, & Miceli, 2008). The Ps-Dm effect has been explained regarding preparatory processes at work which facilitate memory encoding (Galli et al., 2011; Park & Rugg, 2010). However, it remains largely unknown when and how the preparatory processes benefit memory. One reason may be that these studies have largely ignored the electrophysiological literature regarding cortical measures related to anticipation. Namely, that orienting responses to warning cues are separate from the subsequent anticipated stimulus-preceding emotional event. In this project, an attempt has been made to elucidate the mechanism behind the Ps-Dm effect, as well as the preparatory process, by incorporating a theoretical framework from the electrophysiological literature. Therefore, the focus of the current study is on the examination of the neural initiation of different temporal stages of anticipation. This anticipatory model consists of two stages: (1) instant responses to warning cues displayed before negative or neutral pictures and (2) sustained anticipatory responses leading up to the onset of that picture (Birbaumer et al., 1990; Bocker et al., 2001; Grupe et al. 2013). Thus, a theoretical framework based on electrophysiological and cortical measures of anticipation has been adopted, to refine the methodological issues that have been largely ignored in previous Ps-Dm effect ERP studies.

In the first ERP study on Ps-Dm effect, cues remained on the screen for the whole duration of anticipation that was 1400ms and disappeared only a 100ms before the picture was presented (Galli, et al., 2011). It appears that the Ps-Dm effect is confined to that time interval for which the cue remained on the screen. Since the analysis fot the 100ms when the cue disappeared has not been provided in this particular study. Hence, It is still unknown, if Ps-Dm effect sustains during the same anticipatory phase as well when the cue disappears after for a short display of cue while in the rest of the time participants wait for the anticipated stimuli. One possibility might be that Ps-Dm effect is more related to the immediate responses to the cues than to the perception of sustained anticipation activity. Out of 3000ms cue epoch, the current experiment has the cue remain on the screen only for a short duration, i.e., 1000ms. Rest of the 2000ms time participants waited for the stimuli to appear.

The anticipation of emotional stimuli is a non-motor ERP component. From an experimental psychology perspective, *prep*aratory processes involve the activation of the motor system for the execution of a movement (van Boxtel & Böcker, 2004). On a perception-action-continuum, anticipation represents the perception while preparation represents the action domain (van Boxtel & Böcker, 2004). The intermediate processes on this continuum may be activated if a quick action is required in response to the upcoming stimuli. However, if the upcoming stimulus is emotional, these intermediate processes tend to get activated in advance because of the motivational significance of the emotions. ERP literature on anticipation has documented that, slow cortical brain waves are elicited just 200ms before the onset of emotional stimuli. These slow negative wave forms reflects an index of anticipation of emotional stimuli and referred to as Stimulus Preceding Negativity (SPN) (Chwilla & Brunia, 1991; Hillman, Apparies, & Hatfield, 2000). The slow waves are not associated with motor responses; that is why they are identified as the non-motor ERP component specific to emotional anticipation. In those studies, where participants are given explicit instructions to respond quickly to emotional stimuli, the motor response becomes a confound (Galli et al., 2011). It is important to determine whether the Ps-Dm effect is the result of general action-oriented preparation towards upcoming stimuli, or emotional preparation that does not require a motor action. In the current experiment, the picture-rating (SAM valence rating) task is self-paced, and no quick reaction is required. It is done with the consideration that SPN is a non-motor EPR component, and assumes that the emotional anticipation is itself motivationally significant and occurs without a quick reaction to the experimental task.

Anticipatory preparation is an endogenous cognitive process, according to Bozinovski and Bozinovska (2004) and contrasts with expectation/ prediction, which is initiated by some expected external event. That is, anticipation is a more instinctively mediated process, which does not necessarily follow higher-order cognitive functions like expectation or prediction processes. Therefore, higher or lesser brain activation in response to anticipation depends on the expectation of the impending aversive event. For instance, one study found that low pain cues modulate anticipation and dampen brain activation compared to high pain cues (Koyama, McHaffie, Laurienti, & Coghill, 2005). Similarly, the Mackiewicz, Sarinopoulos, Cleven, & Nitschke (2006) study showed greater activation in the amygdala and hippocampus during anticipation of high-arousal negative pictures. Findings from these studies suggest that the perception of high-intensity aversive stimuli led to the Ps-Dm effect. In contrast, a Magnetoencephalography (MEG) study showed that activity in visual evoked magnetic fields (VEF) was reduced in response to emotionally negative cues (Onoda et al., 2007). Together these studies suggest that preparation is a type of adaptive behaviour, which can either depress or enhance brain potentials to deal with the situation.

Preparation increases the efficiency of cognitive processes by eliciting advanced activation of the neural substrates involved in those processes (Bollinger et al., 2010; Irwin, Knott, McAdam, & Rebert, 1966; B. K. Schmidt, Vogel, Woodman, & Luck, 2002). That is, being prepared primes the brain to certain stimuli and responses. In line with this finding, shorter reactions times have been observed in anticipatory trials (Park & Rugg, 2010). Additionally, affective stimuli are deemed motivationally significant and are processed in a prioritized manner. Therefore, in the current experiment, quicker reaction times for rating negative pictures presented with informative cues are expected. In the previous ERP study (Galli et al., 2011), no information on reaction time measures was provided. Therefore, this study was interested in measuring participants' reaction times without them first being given explicit instructions to respond quickly to stimuli (due to the possible confounding effect of a speeded response on the SPN).

5.2.2 Modulation explanation

Anticipation or preparation in response to warning cues is not the only factor behind emotional memory enhancement. Ps-Dm effects have also been observed in the absence of cues not only in the studies which employed power spectral analysis (Fell et al., 2011; Guderian et al., 2009; Noh et al., 2014; Yoo et al., 2012) but also in ERP study that used non-informative cues (Yick, Buratto, & Schaefer, 2015). Another explanation could be that in the absence of some temporal pattern, the amygdala is activated. Amygdala activity subsequently influences activity in other brain areas including the neocortex and hippocampus, thereby facilitating memory formation (McGaugh, 2004). From an evolutionary perspective, the process of predicting some event or perceptual information in time is critical to human survival, since it allows one to escape from danger (Castelfranchi & Miceli, 2011). A situation in which participants are aware of upcoming stimuli might not be physiological as arousing as an unpredictable one (Grillon, Baas, Lissek, Smith, & Milstein, 2004; Grillon et al., 2009; Mineka & Kihlstrom, 1978). Neuroimaging evidence shows greater activation in the human amygdala while processing uncertain (Phelps & LeDoux, 2005; Rosen & Donley, 2006) or ambiguous situations (Whalen, 1998). Herry et al. (2007) observed anxiety-like behaviour in mice in response to unpredictable stimuli. In the second part of the same study conducted on humans, they found greater activation in the amygdala and enhanced attention to emotional facial expressions under unpredictable situations (Herry et al., 2007). Moreover, the subjects perceived and rated unpredictable sound pulses more unpleasant than predictable ones (Herry et al., 2007) and experienced greater pain under uncertainty (Yoshida, Seymour, Koltzenburg, & Dolan, 2013). Activity in the amygdala was also observed under predictable situations; however, this activity was different from the anxiety-like behaviour seen in unpredictable situations in mice. The difference in amygdala activation occurring in response to predictable situations is a result of rapid behavioural habituation. This occurs when predictable patterns in the presentation of some negative stimuli keep activation levels below the behaviourally relevant threshold (Davis, 1970; Herry et al., 2007). Another study's findings revealed enhanced sensitivity to the unanticipated stimuli in female participants (Jin et al., 2013). Taken together, these findings suggest that the emotional context or arousal during the anticipation phase could bias attention towards an upcoming negative stimulus and hence, contribute to the most efficient encoding of emotional stimuli.

5.2.3 Random fluctuation hypothesis

Another possible alternative explanation for the Ps-Dm effect may be the 'random fluctuations in attention' hypothesis (RFH) which rivals the preparatory process and modulation theory (Pincham & Szűcs, 2011). The random fluctuation hypothesis is a speculation based on the findings from a study on emotional memory which demonstrated a Ps-Dm effect for emotional pictures without any specific anticipation (Yick, Buratto, Schaefer, in press). According to this presumption, the Ps-Dm effect does not reflect any encoding component at the pre-stimulus phase. Rather, it is caused by random fluctuations in attention (Bengson, Kelley, Zhang, Wang, & Mangun, 2014) or perhaps due to the shared contribution of physiological reactivity from other sources, such as heart rate (HR), skin conductance (SCR), or facial movements (EMG; Lang et al, 1993; Pace-Schott et al, 2011). It assumes that no memory component is reliable in the pre-stimulus phase if at post-stimulus phase encoding does not occur. It also assumes that the pre-stimulus phase might reflect emotional processing but not that of memory. RFH posits that encoding is a conscious process. Different conscious strategies are used to enhance memory that result in behavioural benefits. In the current study that random fluctuation is a rival explanation if findings will reveal Ps-Dm effect for both cue conditions.

5.2.4 Preparatory process explanation

The preparatory process explanation of the Ps-Dm effect assumes that the mental readiness required to deal with the upcoming stimuli leads to memory formation (Galli, Wolpe, et al., 2011). It is argued that if the purpose of preparation is to facilitate encoding of an emotionally negative event, then one would expect a benefit for emotional memory at the post-anticipation period that was absent in the previous study (Galli, Griffiths, et al., 2012; Galli, Wolpe, et al., 2011). The absence of Dm effect in response to pictures makes the reliability of Ps-Dm effect questionable (Galli et al., 2011; Gruber & Leun; Otten, 2010; Otten et al., 2006; Otten, Quayle, & Puvaneswaran, 2010; Park & Rugg, 2010). It is proposed that for a strong Ps-Dm effect, the pre-stimulus, post-stimulus, and behavioural results may show a linear relation. Without this direct relationship, the Ps-Dm effect might be merely a reflection of random fluctuations in attention and not an index of encoding or preparation at work.

The anticipatory model in this study proposes that pre- and post-anticipation processes are not isolated. Anticipation, preparation, and action are closely linked to each other (Castelfranchi & Miceli, 2011). Anticipation operates by preparing the system to become active soon, either to have more efficient processing, (Castelfranchi & Miceli, 2011; Lobanov, Zeidan, McHaffie, Kraft, & Coghill, 2014; van Boxtel & Böcker, 2004). It was found in studies that involved real electrical shocks and pain that participants' reactions were modulated according to the level of expectation of pain (Koyama, McHaffie, Laurienti, & Coghill, 2005). Brain activity in response to high pain cues differed from activity associated with cues signalling small pain. This signifies that the anticipation is related to the impending emotional event, which in turn plays a role in modulating neural responses at the pre-stimulus phase. In this context, anticipatory activity tends to be linked to post-stimulus activity. Taking together, these studies provide evidence that pre- and post-stimulus mechanisms are not dissociable or inextricable. Although, if they are in fact dissociable, then the findings might be explained regarding 'Random Fluctuation Hypothesis'.

Ps-Dm effects have been studied beyond the ERP literature on cortical measures of anticipation. For instance, the type of cues (pictorial and verbal) and cue duration are two crucial factors in the ERP theoretical framework of anticipation. Before discussing certain drawbacks associated with methodology, a brief review of important cortical measures of anticipation is given. In the electrophysiological literature, anticipation is typically studied using a cueing paradigm that involves two types of stimuli: a cue stimulus (S1) and a picture stimulus (S2). Electrical brain potentials for S1 and S2 are distinguished as the Contingent Negative Variation: CNV (Walter, Cooper, Aldridge, McCallum, & Winter, 1964)) and the Stimulus Preceding Negativity: SPN, respectively. Both ERP components are slow waves with negative-going deflection. However, the CNV is an early wave associated with the properties of the cue (S1). It is larger at frontocentral sites and usually requires a motor response to S2. In contrast, the SPN is a late wave, which is associated with the properties of emotional stimuli (Boxtel et al., 2004; Buodo et al., 2012). Functional significance of the SPN is interpreted as the preparatory activity aimed at speeding up brain processes for emotional stimuli (Luck and Kappenman, 2012).

A brief review of the theoretical framework of the cortical measures of anticipation raised two issues crucial to the explanation of Ps-Dm effect. First, cues were pictorial in nature, that is, cartoon-like faces were used. Second, they remained on the screen for the duration of anticipation (Galli et al., 2014; Galli, Wolpe, et al., 2011). ERP measurement, especially the CNV, is related to the properties of the cues (van Boxtel & Böcker, 2004). By nature, anticipation is a perceptual process (V. Boxtel et al., 2004). It is speculated that the use of pictorial cues might have become confused with the perceptual anticipation. It is plausible that face-like cues were the driver of the Ps- Dm effect rather than legitimate anticipation-related activity. In all the experiments of this project, instead of cartoon faces, the upper case letters O (neutral) and X (negative) have been used. These cues have no intrinsic value; rather they were manipulated as anticipatory attention to stimuli. During the instructions and practice phase, cues were conditioned to the type of upcoming picture. This was done to help participants form a mental representation of the image by applying the perceptual meaning of the cue. That is, representation was tied to the perception of the cues.

The other crucial aspect of the Ps-Dm effect study is that the pictorial cues remained on the screen for the whole duration of the anticipatory period (1400ms) and disappeared only 100ms before the picture onset (Galli, et al., 2011). If the preparatory process hypothesis is reliable, and preparation facilitates encoding at the pre-stimulus phase (for Ps-Dm), then the Ps-Dm effect might have been present at 100ms before the picture onset. The Ps-Dm effect reported in Gallli, et al., (2011) is just specific to the instant response to the cues. Evidence regarding SPN might be focused as an index of preparation for emotional anticipation during the anticipatory phase. About emotional anticipation, SPN can be considered as the ERP counterpart of the emotion effect in emotion memory literature. At the anticipatory phase, it can be measured as the amplitude difference between the brain waves of anticipated emotional and neutral trials. An SPN analysis could yield evidence to support a preparatory process that modulates the Ps-Dm effect. However, no SPN analysis has conducted in the relevant study (Galli et al., 2011).

The findings of the study in Chapter 4 demonstrated that Informative and Non-Informative anticipatory cues modulated emotional memory for recollected pictures at the behavioural level. Memory performance under the No-Cue condition did not yield similar results. Findings of this study led to focus on the neural processing of the anticipatory behaviour, as the data came from a behavioural study and was beyond the scope of that research.

In the current experiment, the event-related potential (ERP) technique has been used to investigate the questions focused on in study 1. To reiterate, does the Ps-Dm effect reflect intentional preparatory processes where the presence of cue is required (cues needed) or is it only result of random fluctuation if similar Ps-Dm activity is seen in the absence of cues.

Ps-Dm effect was investigated by making a distinction between two anticipatory phases: One for the time the cue remains on the screen (0-1000ms) and other when it disappears from the screen from 1000ms to 3000ms till the onset of the picture. In the Info-Cue condition, Ps-Dm effect is expected to be found during the cue display period; it would enable the replication of a preparatory-process-based explanation found in the study by Galli et al. (2011). The Stimulus-Preceding Negativity (SPN), an indicator of affective anticipation, would be examined in the later time windows.

If the Ps-Dm effect was also found in the No-Cue condition, it would indicate that cues or preparatory processing are not necessary to elicit an effect, and findings would be discussed with respect to the random fluctuation hypothesis. Assuming that physiological arousal becomes heightened in the unpredictable condition (Herry et al., 2007), it is predicted that participants would rate negative pictures more negatively in the No-Cue condition.

5.3 Method

5.3.1 Participants

Thirty-nine female participants (mean age = 20.84 years, SD = 4.96 years) volunteered to take part in the experiment in response to departmental participant pool adverts and flyers posted in different buildings of the campus. The basic selection criterion was set as right-handed female participants from any ethnic background, within the age range of 18-45 years, who have had no previous exposure to experiments using emotional images.

Each volunteer went through a screening phase before her participation in the experiment. Questionnaires enquiring about mood (Depression, Anxiety and Stress Scale: DASS: see appendix K), medical history, and suitability for an EEG study (EEG Screening Form: see appendix L) were administered online. The Depression, Anxiety and Stress Scale (DASS) were selected (Lovibond & Lovibond, 1995) to control for potential mood-related biases affecting emotional memory performance. An EEG Screening Form inquired about the use of neurological/psychoactive drugs (e.g. anticonvulsants, antipsychotic, neuroleptic), or any skin or neurological conditions, etc. The participants with neurological or psychiatric problems, and those who scored within the 'Severe to Extremely Severe' range on the DASS scale were not invited to participate in the study. As compensation, the participants who took part in the experiment were compensated for their time with participant pool credits or alternatively remunerated with £15. All had normal and corrected-to-normal vision. The departmental ethics committee approved the use of emotionally negative images in the experiment. Out of thirty-nine tested participants, data from eleven participants were not considered for analysis for reasons outlined in Table 5.1.

Table 5.1: Number of participants excluded from the data analysis with reasons for exclusion

Total Removed	Codes	Reasons for removal
4	152 156 162 172	Artefact-free trails were fewer than the minimum criteria set for the no. of trials per condition for the recognition memory performance.
5	166 174 181 187 188 189	EEG Noise due to high impedances
1	157	Behavioural Outlier: memory performance was more than 3SD above the mean

Table 5.1 shows the details on the files excluded from the final analysis for different reasons. Participants who contributed fewer than 12 artefact-free trials for at least one of the cue conditions were excluded. This criterion is consistent with a number of ERP studies on memory processes (Galli et al., 2011; Gruber & Otten, 2010; Kim, 2011; Padovani, Koenig, Brandeis, & Perrig, 2011).

The statistical analysis was conducted on the final sample of 28 female participants (mean age 19.55 years, and SD = 1.27). The sample was a mix of native English (76%), Chinese (14%) and multi-race individuals (10%). Mean scores of the selected participants fell into the normal to moderate range on the subscales of the DASS, (Depression, X = 2.79, SD= 3.75; Anxiety, X = 3.10, SD= 3.23 and Stress, X= 6.79, SD = 6.05).

5.3.2 Design

It was a repeated measures research design which employed an S1-S2 (Stimulus 1: Cue - Stimulus 2: Picture) Cueing-Subsequent memory paradigm. For the cue stimulus (S1), a letter and a sign (O, #) were used, while emotional and neutral images were used as picture stimuli (S2) selected from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert., 2008; Lang, Bradley, & Cuthbert, 1997). The experimental design constituted two phases: An S1-prestimulus phase and an S2-post stimulus phase. Two conditions were manipulated: An Informative cue, (Info-Cue) condition and a No-Cue condition. In the Info-Cue, the cues provided information as to the valence of the upcoming stimuli. In contrast, in the No-Cue condition pictures were presented without a warning cue and in an unpredictable manner. The ERPs pertaining to cues and pictures were recorded; that is the encoding phase but not for the retrieval phase.

5.3.3 Stimuli and Material

Two types of stimuli were used in the experiment: cue stimuli and picture stimuli. In the Info-cue condition, either an upper case letter O or an X were used as cues for negative and neutral pictures, respectively. The presentation of the cues (O, X) was counterbalanced across participants. During the No-Cue condition, no specific cue was presented. Since ERP activity is time-locked to the stimulus, a fixation signs (+) was required to record electrical activity pertaining to the No-Cue condition. However, there was the possibility that participants could take the presence of the fixation as a cue. To control for this factor, the participants were instructed that the fixation sign was there to help focus gaze in the canter of the screen. Second, the slides were designed in such a way that the No-Cue-related fixation sign display time was randomly varied with three intervals (500ms, 1000ms and

2000ms) beforehand. This time setting did not allow participants to treat the fixation sign as a cue.

Emotionally negative and neutral pictures were selected from the International Affective Picture System; IAPS (Lang, 2005) (350), with the addition of extra stimuli from Google Images (210) that were chosen to match the non-emotional dimensions (presence of human face, human body, animal and object-related pictures) of emotionally negative and neutral pictures across all conditions. All the google images and the selected IAPS pictures were already rated for valence and arousal on a 5- point scale (Valence: 1= negative, 5= positive; Arousal 1= low and 5= High) by a sample of British students (Pottage & Schaefer, 2012; Schaefer, Pottage, & Rickart, 2011). Based on these ratings, 560 pictures were selected and divided into two sets: negative (280) and neutral pictures (280). Average valence score for the negative pictures was 1.90, SD = .03; mean arousal score: 3.32, SD = .51 and for neutral pictures (mean valence score: 3.21, SD = .25; mean arousal score: 1.85, SD = .33). The selected picture sets differed significantly on valence t (558) = 46.37, $p < .001$ and arousal ratings t (558) = 39.50, $p < .001$ according to the normative rating given in the IAPS manual. Emotionally-negative pictures were categorized as high and low arousal through a median split. The mean arousal score was significantly ($p< .001$) different for high (HA) and low arousal (LA) picture categories (HA = 3.73, SD = .34; LA: mean = 2.90, SD = .25). All the pictures were resized into 500 × 375-pixel format.

The selected set of 560 IAPS pictures were first split into 384 (Negative = 192; Neutral = 192) and 160 (Negative = 80; Neutral = 80) picture sets to be used for the encoding and retrieval phases of the experiment, respectively. The remainder of the 16 pictures was used for the practice block. In the study phase, an equal number of negative and neutral pictures were presented under Info-Cue and No-Cue conditions. Informative and No-cue trials were presented randomly in 8 experimental blocks with 48 trials in each. For each of the cue conditions, negative and neutral pictures were presented randomly. Each block contained an equal number of trials for all the relevant factors, such as cue conditions, negative and neutral pictures, high and low arousal pictures, as well as an equal representation of the three inter-trial time intervals (500ms, 1000ms, 2000ms). A short rest break was given after each block. The old/new status of the negative and neutral pictures and block order was counterbalanced across participants.

The test phase consisted of a total of 544 images: 384 old pictures and 160 new pictures (80 negative and 80 Neutral). Each trial in the test phase was mainly concerned with a memory test; however, cues were presented prior to each picture display. This was done to keep the stimulus presentation parameter constant across encoding and retrieval phases. Old and new negative and neutral pictures were presented randomly in each block. The order of the blocks was counterbalanced across participants.

5.3.4 Procedure

After the initial screening phase, participants were invited to the EEG lab in the Wolfson Research Institute for their participation in the experiment. They gave informed consent acknowledging that they would be exposed to emotional images and that they had the right to withdraw from the study at any time without penalty (see Appendix J). They also signed a paper copy of the EEG screening form (see Appendix L) for the lab data record purposes. Afterwards they were given instructions (Study phase instruction sheet see Appendix M) as follows:

> *"You will see a series of neutral or negative pictures. In some trials, a cue (**#** or O) will appear before presenting the pictures. # indicates that the picture is going to be neutral while O indicates that the picture is going to be negative. Please, pay attention to these cues and get yourself ready to see the type of pictures the cue informs about. In other trials, no cue will appear before presenting the pictures. After seeing each picture, rate how the picture made you feel on a 5-point scale ranges from a **frown** (button 1) to a **smile** (button 5). If the image made you feel unhappy, disgusted, or upset, enter 1 or 2. If it made you feel neither pleased nor upset (neutral), enter 3. In case, you feel happy, pleased, or content while seeing the picture then, enters 4 or 5".*

After the instructions, the study/encoding phase started where participants were presented with cues and corresponding pictures. Details are as follows:

5.3.4.1 Study/Encoding Phase

Participants were seated in a comfortable position, approximately 70cm away from the 19" computer screen. Prior to the main experiment, participants went through a practice block with 12 trials to ensure that they were able to associate the cues with the valence of the pictures. Stimuli presentation and response data were controlled using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) running under Windows 7 on a Dell Latitude 6500 desktop, with a resolution of 1,024 × 768 pixels on a 40 cm × 30 cm Samsung SyncMaster computer screen (TCO'03 Displays, MagicBright). The accuracy of the synchronization between stimuli onsets and triggers received by the EEG system were checked using the BlackBox Toolkit (BlackBox Toolkit Ltd., York, UK).

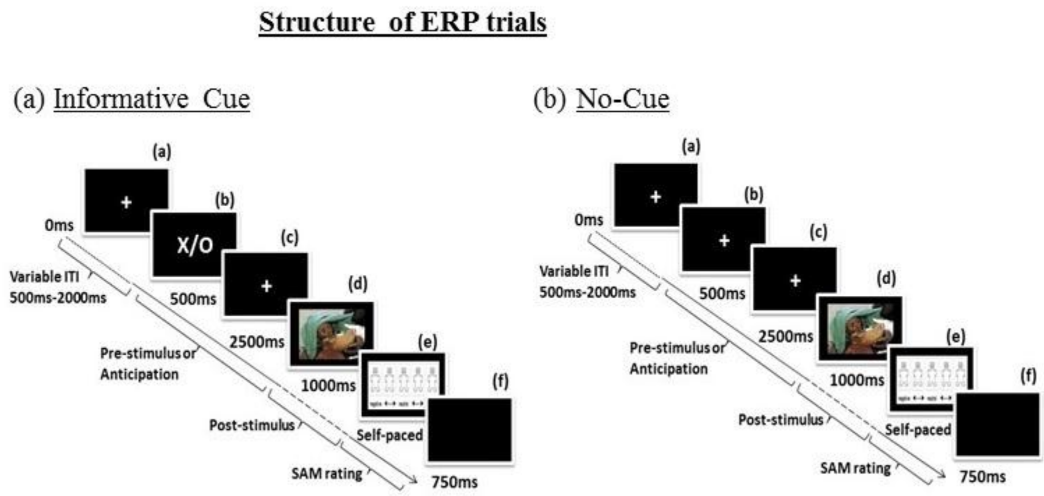


Figure 5.1: Encoding phase- Schematic of the Experimental Trial

a) Each study trial began with the presentation of a fixation point (+). The duration of this fixation point varied between 500ms; 1000ms and 2000ms set as inter-trial intervals.

b) Participants were presented with informative negative and neutral cues (X/O) for 500ms while for No-Cue a fixation sign remained on the screen for the same time period.

c) Another fixation sign remained on the screen for 2500ms.

d) Pictures were displayed on the computer screen for 1000ms.

e) Participants had to rate the valence of each picture using the self-paced Self-Assessment Manikin (SAM: Bradley, 1994) valence rating with the help of a response box after the picture disappeared.

f) There was a blank screen at the end of each trial. The idea was to have a brief delay before the continuous appearance of the fixation (+) sign on the screen.

5.3.4.2 Test/ Retrieval Phase

The test phase followed the study phase after an interval of 24 hours to allow for better consolidation of emotional memories (Sharot, Verfaellie, & Yonelinas, 2007; Sharot & Yonelinas, 2008). Since it was an incidental memory test, upon arrival of the participants in the lab, they were told that their recognition memory would be tested. They were provided with an instruction sheet which explained the two experimental tasks: A Confidence rating task and a Remember/Know judgment task (R/K). Instructions in brief are as follows:

"You will be shown a set of "old" pictures (seen yesterday) and "new" pictures (not seen yesterday). Your task is to decide, for each picture, whether it is Old (previously seen) or New (previously unseen). Further, you are required to rate Old/ New responses on a 3-point confidence scale as, "Guessing, somewhat sure, or absolutely sure". If you give confidence rating as "old", you will be asked to further decide if it is a "remember memory" or "know memory. In case your response is "New", you will be asked for a dummy response (Left/right) by a specific button press".

Participants were trained for the R/K judgments (for full instructions see Appendix N) through a practice block given prior to the actual test. It was made sure that they fully comprehended the R/K task by giving them feedback on the practice block. The pressing of "left/right' keys, followed by "New" was not imperative to the experiment, but rather present just to equate the motor activity followed by an 'Old" response. Responses were computer-recorded and no time limit was imposed for the confidence rating and R/K judgment task. A schematic illustration is given in Figure 5.2.

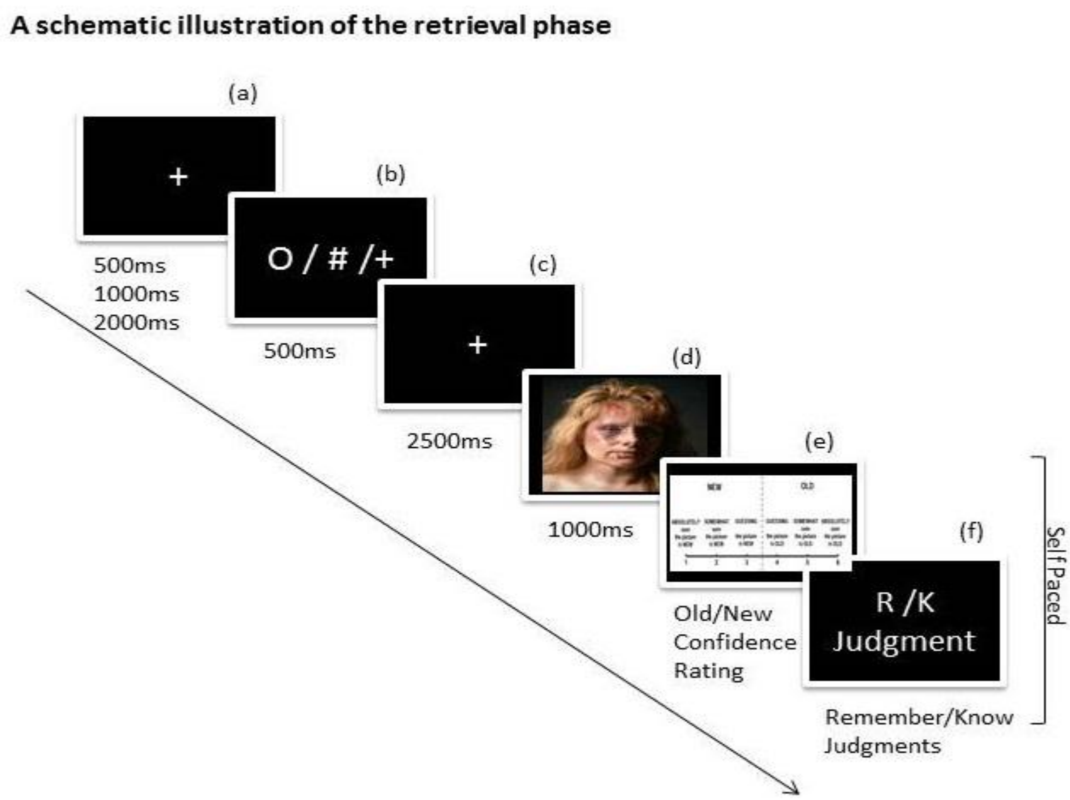


Figure 5.2: Test phase- Schematic of the Experimental Trial

(a) The test phase trial was similar to the study phase trial from a through c.

(d) Old and new pictures were shown to the participants for 1000ms.

(e) Participants rated old/new items on a six-point confidence rating scale.

(f) Participants also judged if the recognition memory came with a feeling of recollection or familiarity: Remember-Know judgment.

Since memory test was incidental, therefore a debriefing form was given to the participants to make it sure that they leave with a good feeling about their participation in scientific research (see appendix O). Moreover, for follow-up care, counselling or a summary of the research finding, participants signed a result follow-up form (see Appendix P).

5.3.5 Electrophysiological Data Recording and Processing

EEG was recorded from a 64- channel cap (Waveguard, ANT Inc., Enschede, The Netherlands). The sampling rate was 512Hz (DC-138Hz bandwidth). The impedance was kept below 5kΩ. EEG data was recorded using an average reference and digitally converted to a linked-mastoid reference. An ERP module of BESA 5.3 (MEGIS software GmbH, Gräfelfing, Germany) was used for analysis of the EEG data. Stimuli presentation and response data were controlled using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) running under windows 7 on a Dell latitude 6500 desktops, with a resolution of 1,024 × 768 pixels on a 40 cm × 30 cm Samsung SyncMaster computer screen (TCO'03 Displays, MagicBright). Stimuli presentation accuracy and trigger signals received by the EEG system were controlled using the BlackBox Toolkit (BlackBox Toolkit Ltd., York, UK).

Pre- and post-stimulus data were digitally filtered offline 0.03-20 Hz; 0.03-30 Hz, respectively and corrected for eye movements (Berg & Scherg, 1994). Data were segmented into epochs between (-200ms to 3000ms) for cues and (-200ms to 1000ms) for picture-related brain activity and baseline corrected.

ERP waveforms were created by averaging EEG data for remembered trials and forgotten trials separately, for Info-Cue and No-Cue trials, and for both emotionally negative and neutral cues, resulting in 8 trial types: Info-negative-remembered, Info-negative-forgotten, Info-neutral-remembered, Info-neutral-forgotten, No-Cue-negative-remembered, No-Cue-negative-forgotten, No-Cue-neutral-remembered, No-Cue-neutral-forgotten. The mean number of artefact-free trials per condition was: 35.36, 18.89, 23.36, 28.50, 32.61, 18.68, 23.89, 27.14, respectively. Participants with less than 12 artefact-free trials were excluded from the analysis. This criterion is in line with many previous ERP studies on memory processes (Galli et al., 2011; Gruber & Otten, 2010; Padovani, Koenig, Brandeis, & Perrig, 2011; Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014).

5.3.6 Electrode clusters

Data recorded at 64 individual electrodes were pooled together to form 6 electrode clusters spanning over frontal, central, and centroparietal scalp regions. The literature shows that the Dm effect for pictures is observed over the frontocentral and centroparietal scalp site, which varies as a function of the type of task and material used (Olofsson, Nordin, Sequeira, & Polich, 2008). The clusters consisted of the following electrodes: left anterior (F7, F5, F3, FT7, FC5, FC3), midline anterior (F1, Fz, F2, FC1, FCz, FC2), right anterior

(F8, F6, F4, FT8, FC6, FC4), left posterior (P7,P5, P3, TP7, CP5, CP3), midline posterior (P1,P2, Pz, CP1, CP2, CPz), and right posterior (P8,P6, P4, TP8, CP6, CP4) based on literature for the encoding-related post-stimulus SM effect analysis.

5.3.7 Time bins for Picture-Locked ERP Analysis

The time bins selected for Picture-locked data analysis included: 50-100 ms, 0-100 ms, 100-200 ms, 200-300 ms, 400-1000ms. These time windows were chosen on the basis of careful visual inspection of the picture-related ERPs and the previous literature investigating early and late picture-locked memory-related components, i.e., SME.

P1 was defined as the first positive amplitude and N1 as the maximal peak amplitude in the 50-100ms time window. Th amplitude for P2 was extracted from the 150-200ms time window. N2 is the most important visually-evoked component and was investigated between 200-300 (Folstein & Van Petten, 2008). Here, we expected to find a difference in the mean amplitude of this component for emotional anticipation compared with that for the anticipation of neutral stimuli or where there is an absence of anticipation. P3 is considered as an indigenously generated component and was targeted in the 300-400ms time window.

Finally, the mean amplitude was computed in the 400-1000ms time window to capture the well-documented Dm effect over frontocentral (Friedman & Trott, 2000; Otten et al., 2006) and centroparietal electrodes (Fabiani, Karis, & Donchin, 1990). The Dm effect has been characterized by a larger positivity for remembered versus forgotten trials (Paller & Wagner, 2002). To see how the post-stimulus Dm is modulated by the presence and absence of cues.

5.3.8 Time bins for Cue-Locked ERP Analysis

Since the Ps-Dm effect is not yet as well-documented as the Post-Stimulus Dm effect, there is inconsistency in findings of the latency of the Ps-Dm effect (Galli, Wolpe, et al., 2011; Padovani et al., 2011). The lead researchers (Otten, Quayle, Akram, Ditewig, & Rugg, 2006) themselves have found this effect in different time windows for different cue stimuli and for different experimental task/methods. A few examples of this inconsistency are provided here. In their initial study, this effect was observed between -250-0ms before the word onset (Otten et al., 2006), 750-1250ms (Otten et al., 2010), in three time windows including 200-300ms, 300-600ms, 600-1100ms after cue onset (Gruber & Otten, 2010) -1300 to -1700ms before word onset (Padovani et al., 2011), and for emotional cues between 300-1500ms (Galli et al., 2011).

The Ps-Dm effect was found to be largest over the right frontal electrode site (Galli et al., 2011) and in a recent study on centroparietal scalp sites (Galli, Griffiths, & Otten, 2014). The same scalp regions would be examined for Ps-Dm effects. Time bins for the cue-related analysis included: 400-1000 ms, 1000-3000 ms, and 2800-3000 ms to capture the Ps-Dm effect. However, the first time window (~0ms-1000ms) was crucial for the Ps-Dm effect for two reasons: first, it is the time duration for when the cue remained on the screen during anticipation, and second, the Ps-Dm effect in a previous study (Galli, Wolpe & Otten, 2011) was found during the 0-1500ms time duration with a positive-going waveform for emotionally remembered events at the right scalp site. The second time window (1000-3000ms) was selected and examined in order to find evidence of the Ps-Dm effect during the sustained anticipation phase, which occurs after the cue disappears and the onset of the upcoming picture. The third time window (2800-3000ms) was chosen to capture the Stimulus-Preceding Negativity (SPN), which had been observed 200ms prior to the display of emotional pictures in a number of studies (Boxtel & Brunia, 1994).

Therefore, it was expected to get a Dm effect during the Info-Cue condition with a positive-going waveform during anticipation of negative remembered pictures with frontal right-lateralization in the three-time windows. ERP amplitudes from the cluster sites were submitted to a repeated measures ANOVA that incorporated the following factors, (1) Cues (Info-Cue vs. No-Cue), (2) Valence (Negative vs. Neutral Cues/Pictures), (3) Memory (Remembered vs. Forgotten), (4) Anteriority (Anterior vs. Posterior), (5) Laterality (Left vs. Right vs. Midline). For conciseness and given the focus on the Dm effect, the effects involving the memory factor were preferentially targeted. All results were considered reliable at $p < .05$, and partial eta-squares were reported in order to provide estimates of effect sizes. All tests of sphericity where necessary showed that the assumption was met, as assessed by Mauchly's test of sphericity ($p > .05$).

5.4 Results

5.4.1 Behavioural data Analysis

Behavioural analysis in this section is same as given in chapter 4. For details of all the initials, rational and the justification of the analysis is given on page 90 (section 4.3.4. Statistical analysis).

5.4.1.1 Recognition data: Hit-rates, R-hits, K-corr-hits and False Alarm

A 2 (Cue: Informative, No-Cue) × 2 (Valence: Negative, Neutral) repeated measures ANOVA was conducted for HR, R-hits, FA and K-corrected separately. ANOVA for HR revealed a significant main effect of Valence *F* (1, 27) = 34.71, *p* = .001, $\eta 2p$ = .563, that is negative pictures were recognized more than neutral pictures (M_{HR}= .77, .67; *SEs* = .013, .020). The main effect of Cue condition and Cue × Valence interaction was non-significant, (*F's* < 1.07, *P's* > .309). A separate ANOVA for R-hits judgments also revealed a significant main effect of Valence, *F* (1, 27) = 41.17, *p* = .001, $\eta 2p$ = .610, that's negative pictures were recognized more than neutral pictures ($M_{R\text{-}hits}$= .39, .27; *SEs* = .025, .021, respectively). Cue × Valence interaction was also significant, *F* (1, 27) = 5.60, *p* = .025, $\eta 2p$ = .172. Cue wise simple effect analysis showed a highly significant results for both Cue conditions, i.e. Info and No-Cue, *F* (1, 27) = 45.40, 29.63, *p* = .001, $\eta 2p$ = .627, .523, respectively. However, the main effect of Cue, *F* (1, 27) = 2.44, *p* = .130, $\eta 2p$ = .083 was not significant. To get an independent measure of familiarity judgments K responses, K-corrected ANOVA was computed. Findings indicated just significant main effect of Cue condition, *F* (1, 27) = 4.08, *p* = .05, $\eta 2p$ = .131, where scores for No-Cue condition was significantly higher than Informative cue condition, ($M_{K\text{-}corr}$ = .59, .57; *SEs* = .019, .021). K-corrected was also significantly affected by Valence, *F* (1, 27) = 11.62, *p* = .002, $\eta 2p$ = .301, and scores for negative were higher than neutral ($M_{K\text{-}corr}$= .61, .54; *SEs* = .020, .024). Cue × Valence was non-significant, (*F < 1*). Repeated measure ANOVA on false alarm (FA) revealed significant main effect of Valence, *F* (1, 27) = 14.92, *p* = .001, $\eta 2p$ = .356, (M_{FA} = .24, .20; *SEs* = .026, .022). The main effect of Cue condition and the interaction between Cue × Valence was non-significant, (*F's* < .23, *P's* > .63). Table 5 summarizes the results for Hit rates, R-hits, K-hits and false alarms (FA).

Table 5.2: Proportions of "Old" responses on the recognition memory test as a function of Cue condition, Picture Valence and memory performance

		Negative		**Neutral**	
Cues	**Picture status**	*M*	*SD*	*M*	*SD*
Informative	Hit-rates	.78	.07	.66	.12
	R-hits	.41	.13	.27	.11
	K-hits	.37	.12	.39	.13
	FA	.25	.15	.20	.12
No-Cue	Hit-rates	.78	.08	.68	.11
	R-hits	.38	.14	.27	.11
	K-hits	.40	.13	.40	.11
	FA	.24	.14	.19	.13

Note: Proportion of Hit rates is the sum of the proportions of "Remember (R-hits)" and "Know" (K-hits) responses. The data, "K-hits" corresponds to the uncorrected know responses. The data for the corrected know responses K-corr = K/(1-R) is given in the text. False alarm rate is proportions of old responses to new pictures.

5.4.1.2 Pr-Index: Recognition Memory Accuracy for HR, R-hits and K-corr

The *Pr* score for overall recognition memory score (HR) items was significantly higher for negative compared to neutral items, F (1, 27) = 9.26, p = .005, $\eta 2p$ = .255, (M_{HR} = .52,.47; *SEs* = .027, .027, respectively) The main effect of Cue and Cue × Valence interaction was non-significant, (*F's* < .99, *P's* > .32). The *Pr* score for R-hits were also significantly higher for negative compared to neutral items, $M_{R\text{-}hits}$ = .15, .07, *SE* = .036, .027 respectively, F (1, 27) = 12.41, p = .002, $\eta 2p$ = .315. The main effect of Cue and the Cue × Valence interaction was non-significant, (*F's* < 2.71, *P's* > .11). The *Pr* score for corrected K responses was also calculated. Non-significant main effect of valence showed that it was not affected by the negative emotionality of pictures, F (1, 27) = 1.30, p = .26, $\eta 2p$ = .046. Overall, these results indicate that emotion enhances recognition when items are accompanied by a feeling of remembering (R) but not familiarity (K). Figure 5. 3 illustrates these results.

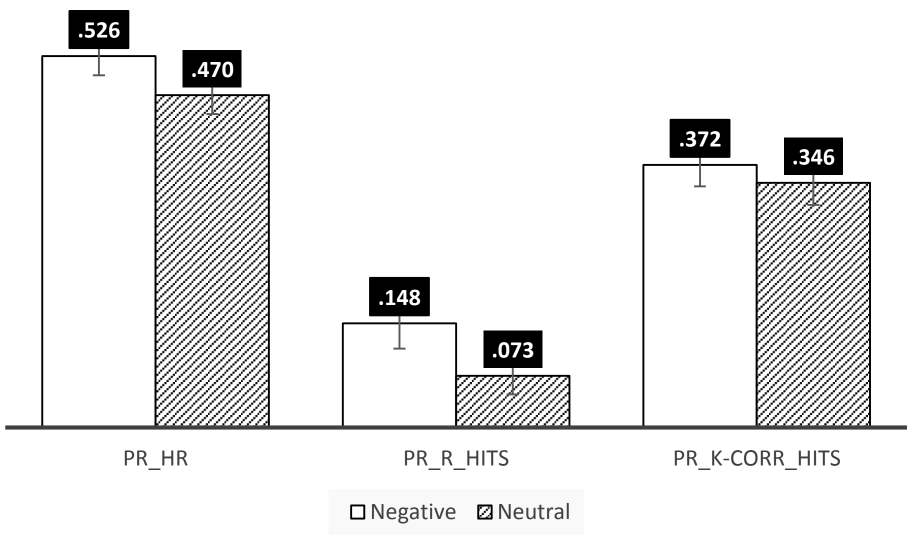


Figure 5.3: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of Valence.

Memory performance was measured with Pr, the difference between Hit-rates, R-hits, K-corr-hits and false alarm. *Pr-index* varies from 0 -1 (no discrimination between studied and unstudied pictures to perfect discrimination). Error bars show the standard error of mean

Further, data were also analysed as a function of cue conditions. For this purpose, recognition memory data was split by cue condition to find the differences in the memory accuracy between valence categories. Simple main effects analysis of Pr index of Hit-rates (HR) revealed a significant main effect of the Informative cue condition, F (1, 27) = 7.69, p = .010, $\eta 2p$ = .22. Overall mean scores on Pr-Index were higher for negative ($M_{Info\text{-}neg}$= .52, *SEs* = .031) as compared to neutral pictures ($M_{Info\text{-}neu}$= .46, *SEs* = .031). Main effect for No-cue condition was also significant, F (1, 27) = 5.39, p = .03, $\eta 2p$ = .166, indicating a higher mean score for negative pictures than neutral ($M_{Info\text{-}neg}$= .53, SEs = .027; $M_{Info\text{-}neu}$= .48, SEs = .025).

Simple main effects analysis of Pr index of 'remembered' responses (R-Hits) revealed a significant main effect of the Informative cue condition, F (1, 27) = 15.31, p = .001, $\eta 2p$ = .362. Overall mean scores on Pr-Index were higher for negative ($M_{Info\text{-}neg}$= .16, SEs = .036) as compared to neutral pictures ($M_{Info\text{-}neu}$= .07, SEs = .028). A significant main effect was also obtained for No-Cue condition, F (1, 27) = 5.87, p = .02, $\eta 2p$ = .179, ($M_{Info\text{-}neg}$= .14, SEs = .038; $M_{Info\text{-}neu}$= .08, SEs = .028).

Pr index of corrected 'Know' responses (K-corr-hits) was also put to the simple main effect analysis. Main effects of the Informative F (1, 27) = .959, p = .336, $\eta 2p$ = .034 ($M_{Info\text{-}neg}$= .36, SEs = .036; $M_{Info\text{-}neu}$= .33, SEs = .036) as well as No-Cue condition were non-significant (1, 27) = .84, p = .37, $\eta 2p$ = .030, $M_{Info\text{-}neg}$= .38, SEs = .030; $M_{Info\text{-}neu}$= .36, SEs = .029 (see figure 5.4 for illustration).

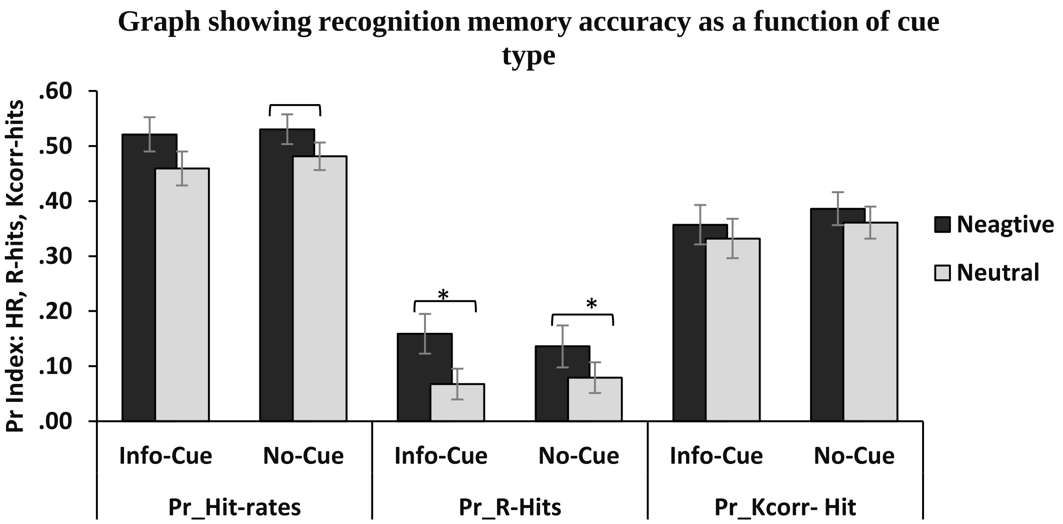


Figure 5.4: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of cue conditions.

Memory performance was significant only for R-hits for both cue conditions: Informative and No-Cue conditions. Error bars show the standard error of mean

5.4.1.3 Valence Rating by participants across cue conditions

It was predicted that the participants would rate negative pictures as more negative during the No-Cue condition. In the No-Cue condition, the participants were not able to anticipate the valence of the upcoming picture, thus increases levels of uncertainty, which is known to cause emotional arousal (Rubio et al., 2014) To test the prediction, a 2 × 2 repeated measures ANOVA was performed on the factors Cue × Valence Ratings by the participants. Findings revealed a significant main effect for Cue F (1, 27) = 13.37, p = .001, η^2p = .323 and rating of pictures F (1, 27) = 515.34, p = .001, η^2p = .94. Moreover, the interaction between Cue × Valence Ratings was also significant F (1, 27) = 8.00, p = .009, η^2p = .22. Further data was split by the valence rating (high and low arousal rating by participants) to examine whether the rating of high and low arousal pictures was different across the cue conditions. A significant effect of Cue was found for low arousal pictures F (1, 27) = 16.87, p = .001, η^2p = .385, and in the No-Cue mean ratings were less (M = 1.96, SE = .045) than the rating in the Info-Cue condition (M = 2.08, SE = .048). In contrast, for high arousal pictures the Cue effect was non-significant, F (1, 27) = 1.626, p = .213, η^2p = .057.

5.4.2 Cue-Locked ERP Analysis

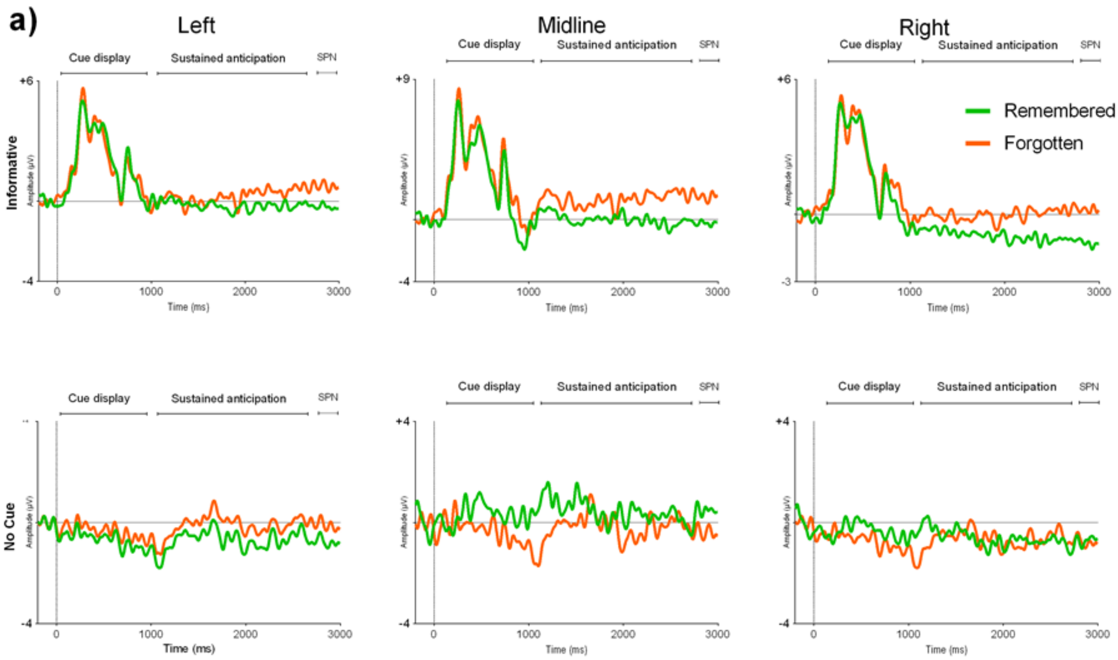
To investigate the difference between the Ps-Dm effect across Info-Cue and No-Cue conditions, the cue epoch (0-3000ms) was divided into two time windows (0-1000ms and 1000ms-3000ms).

5.4.2.1 400-1000 ms: Early waves

A repeated measures analysis in this time window revealed a significant main effect of Cue condition F (1, 27) = 12.88, p = .001, η2p = .323, indicated an overall larger positivity for the Info-Cues *(M* = 5.21, *SE* = 1.61) than for the No-Cue condition *(M* = -3.66, *SE* = .96), and a significant main effect of Valence F (1, 27) = 4.58, p = .041, η^2p = .145, indicated that electrical potentials pertaining to the anticipation of negative pictures elicited more positive going deflection (*M* = 3.79, *SE* = 1.36) than the anticipation of neutral pictures (*M* = 1.05, *SE* = 1.14). A significant interaction was found for the Cue × Memory × Laterality F (1, 27) = 4.57, p = .015, η2p = .145. Subsidiary analysis revealed a significant interaction for Memory × Laterality F (1, 27) = 4.03, p = .023, η2p = .130 for the Info-Cue condition only. Further ANOVA analysis showed that this memory effect was not significant at any scalp site (*Fs* < 1.90, *Ps* > .179). Overall, these findings showed that regardless of valence, brain potentials for the Informative remembered cues were different from the No-Cue condition.

5.4.2.2 1000-3000ms: Late waves with -200 baseline

The Valence × Memory × Anteriority × Laterality, *F* (1, 27) = 3.745, *p* = .030, *η2p* = .122 interaction was significant. To elucidate this interaction, a Memory × Anteriority × Laterality ANOVA was further computed for negative and neutral cues, separately. For negative cues, this interaction was found to be non-significant *F* (1, 27) = 2.145, *p* = .127, η2p = .074. However, for neutral cues a marginally significant interaction was found for Memory × Anteriority, *F* (1, 27) = 3.742, *p* = .064, *η2p* = .122. However, decomposing the interaction revealed no reliable effects for Memory at Anterior, *F* (1, 27) = .859, *p* = .362, *η2p* = .031 or posterior electrodes, *F* (1, 27) = .082, *p* = .776, η2p = .003. Another significant interaction was found for Cue × Memory × Laterality *F* (1, 27) = 6.40, *p* = .003, η2p = .192. Subsidiary analysis revealed a significant Memory × Laterality *F* (1, 27) = 3.43, *p* = .040, *η2p* = .113, interaction for Informative cues, but not for the No-Cue *F* (1, 27) = 2.96, *p* = .060, η2p = .099. This Memory × Laterality interaction for the Info-Cue condition was driven by an effect of memory visible at midline scalp site *F* (1, 27) = 6.695, *p* = .015, η2p = .199 but not at the left *F* (1, 27) = 1.20, *p* = .282, η2p = .043 and right *F* (1, 27) = 1.79, *p* = .192, η2p = .062 site (see figure 5.4).



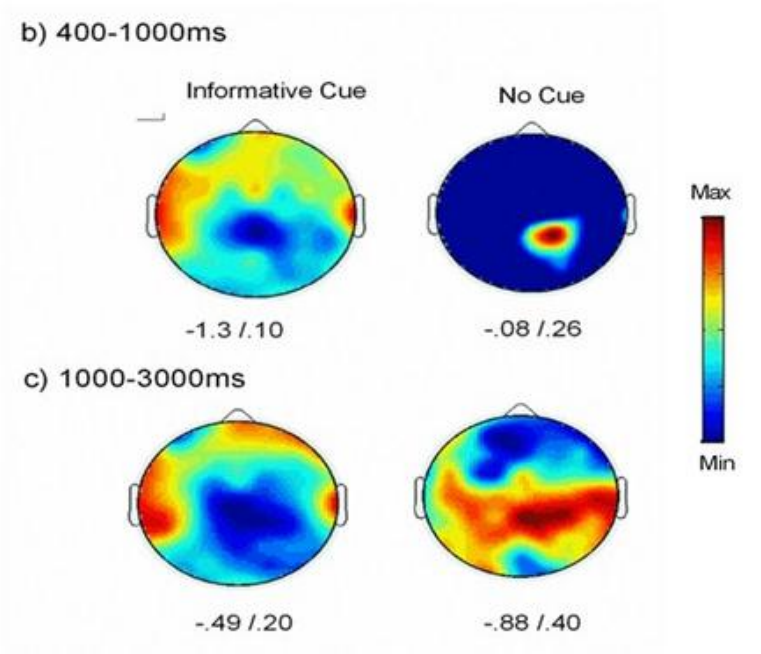


Figure 5.5: ERP waveform and Scalp maps representing cue related activity across picture valence.

a) ERP waveform plotted on left, midline, and right electrodes for cue-related activity according to subsequent memory (Remembered vs. Forgotten items) and cues (Informative vs. No Cue). Amplitude in microvolts is on the y-axis and time in milliseconds is on the x-axis.

b) Scalp maps plotting 'remembered' minus ' forgotten' mean ERP amplitude scores for 400-1000ms

c) Scalp maps plotting 'remembered' minus ' forgotten' mean ERP amplitude scores for 1000-3000ms.

5.4.2.3 1000-3000ms: Late waves with -1200 baseline

Separate analysis was performed for the sustained anticipatory period which is the period from 1000 time 3000ms when the cue disappears from the screen. For this purpose, a new -1200ms baseline period selected after using a 15 Hz filter to exclude the influence of neural activity generated due to the presence and absence of cue. Repeated measures ANOVA was conducted for the whole sustained anticipatory epoch with factors, Cue × Valence × Memory × Anteriority × Laterality. Interaction of interest Cue × Valence × Memory × Anteriority × Laterality was non-significant F (1, 27) = 1.02, p = .37, $\eta 2p$ = .037. However, analysis revealed a significant main effect of cue condition F (1, 27) = 4.61, p = .041, $\eta 2p$ = .146, indicated an overall larger negativity for the Info Cue (M = -1.56, SE = .337) compared to No-Cue condition (M = -1.88, SE = .338). Other significant interaction was Cue × Valence × Anteriority F (1, 27) = 7.86, p = .009, $\eta 2p$ = .225. For this interaction further ANOVAs were conducted by cue categories. For No-Cue condition ANOVA revealed a significant Valence × Anteriority interaction F (1, 27) = 5.81, p = .023, $\eta 2p$ = .177 but not for Info-cue condition *F* (1, 27) = 2.15, *p* = .154, *η2p* = .074. Further subsidiary analysis for Valence categories at each scalp site (anteriority and posterior) revealed no significant difference. Simple effect analysis revealed a non-significant difference between amplitude of negative versus neutral picture for sustained anticipation at anterior *F* (1, 27) = .043, *p* = .837, *η2p* = .002 and posterior scalp sites *F* (1, 27) = .811, *p* = .376, *η2p* = .029.2800-3000ms: Stimulus Preceding Negativity (SPN)

A non-significant interaction was found for Cue × Valence, *F* (1, 27) = 3.75, *p* = .063, η2p = .12. No main effects or interactions reached significance (*Fs* < .667, *Ps* > .421) for this time window.

5.4.2.4 Cue-related early peaks analysis

A visual examination of the cue-related ERP revealed three positive-going peaks at the anterior scalp site as compared to posterior. To examine if the valence and memory-related differences were captured by any of the earlier peaks after the cue onset, mean amplitudes were extracted from three-time windows: (200-350ms), (350-600ms), (700-800ms).

5.4.2.5 P1: 200-350ms

There was a significant main effect of Cue, *F* (1, 27) = 36.53, *p* < .001, η^2_p = .575 indicating a positive-going waveform for Info-Cue (M = 13.53, SE = 2.06) compared to No-Cue (M = .343, SE = .97) conditions. The main effect of Valence *F* (1, 27) = 6.86, *p* < .014, η^2_p = .203 was significant with more positive going deflection for negative cues (M = 8.13, SE = 1.25) than neutral cues (M = 5.74, SE = 1.29). No other main effects or interactions reached significance (F's < .140, p's > .711).

5.4.2.6 P2: 350-600ms

A significant interaction between Cue × Valence × Laterality, *F* (2, 54) = 8.41, *p* < .001, η^2_p = .238 was found. In order to better understand this interaction, a subsidiary Valence × Laterality ANOVA was computed separately for Informative and No-Cue conditions. For the Info-cue, a significant interaction was found for Valence × Laterality *F* (2, 54) = 7.61, *p* < .001, η^2_p = .220 indicating that amplitude for negative pictures were more pronounced with a positive going deflection at midline (M = 75.511, SD = 50.30) compared to right lateralization (M = 45.86, SD = 53.96).

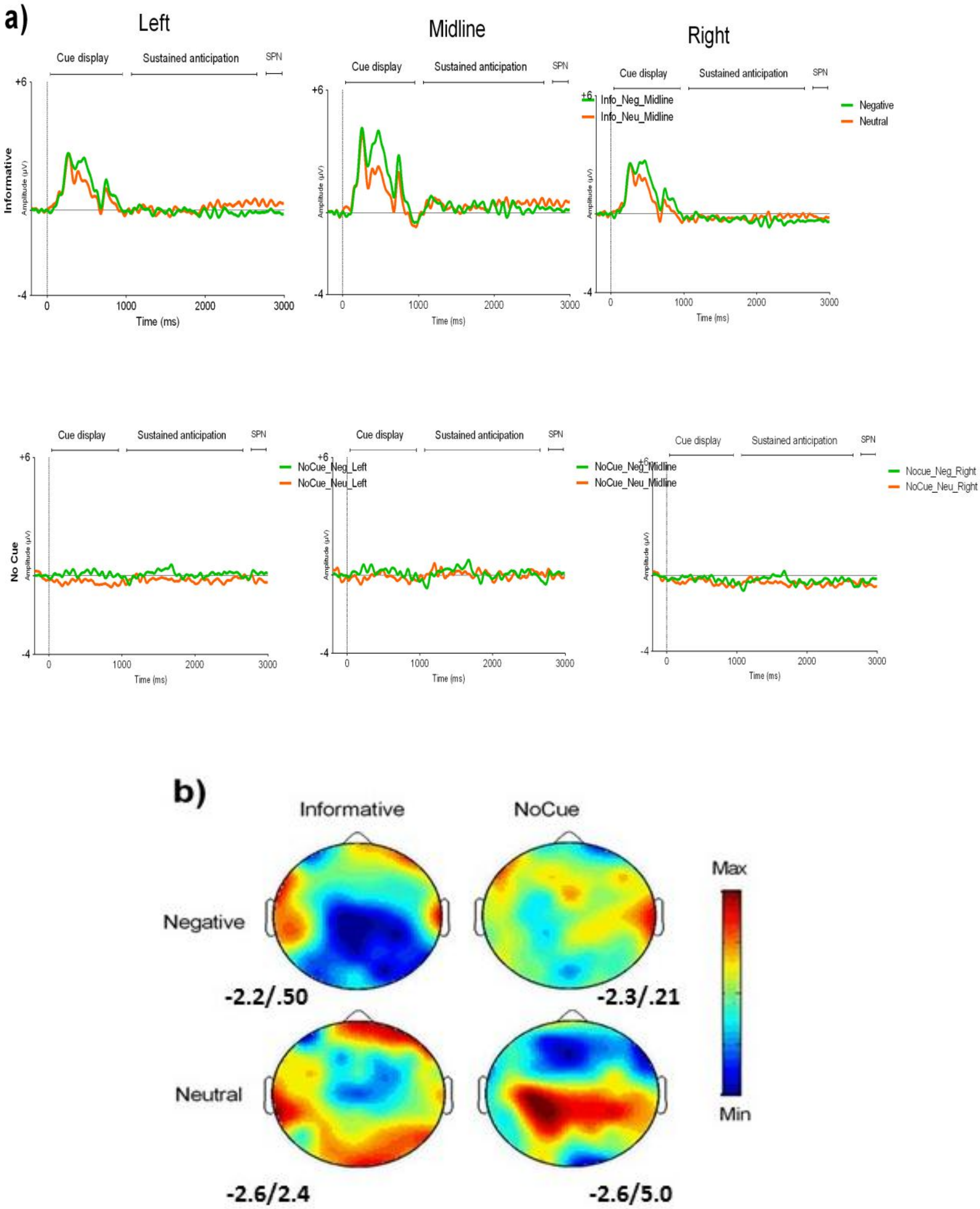


Figure 5.6: ERP waveform and Scalp maps representing cue related encoding activity across picture valence for 350-600ms time bin.

a) ERP waveform plotted on left, midline, and right electrodes for cue-related activity according to subsequent memory (Remembered vs. Forgotten items) and cues (Informative vs. No Cue). Amplitude in microvolts is on the y-axis and time in milliseconds is on the x-axis.

b) Scalp maps plotting 'remembered' minus 'forgotten' mean ERP amplitude scores for 350-600ms.

5.4.2.7 P3: 700-800ms

In this window the Valence main effect that appeared in the earlier two time windows (200-350ms and 350-600ms) disappeared in the time window as the Valence main effect, F (1, 27) = 1.68, p = .206, η^2_{p} = .059 was non-significant. Main effect of Cue type was significant F (1, 27) = 33.92, p = .001, η^2_{p} = .548, reflecting an overall positivity for the Info-Cue (M = 8.43, SE = 1.77) than for the No-Cue condition (M = -2.60, SE = 1.29). No other effects reached significance

5.4.3 Picture-Locked ERP Analysis

The pictures were displayed on the screen for 1000ms. Picture-locked ERP analysis was aimed at examining the conventional Dm effect during 400-1000ms post-stimulus epoch. It was also aimed at examining the evidence for whether anticipation modulated early ERP components in this phase.

5.4.3.1 Post-stimulus Dm effect: 400-1000ms time window

In the post-stimulus phase, a repeated measures ANOVA revealed a main effect of memory F(1, 27) = 29.55, p = .001, η2p = .523, indicating a greater positivity for remembered pictures (M = 13.43, SE = 2.26) than for forgotten ones (M = 7.71, SE = 2.13). The main effect of Valence was also significant F (1, 27) = 56.85, p = .001, η2p = .678, with negative pictures (M = 16.56, SE = 2.73) eliciting greater positive-going deflection than neutral pictures (M = 4.59, SE = 1.69). A significant interaction for Valence × Memory F(1, 27) = 4.75, p = .038, *η2p* = .150 was found. Simple effect analysis for negative and neutral pictures indicated an overall positivity for subsequently remembered items compared to forgotten items for both negative and neutral pictures, Fs (1, 27) ≥ 6.51, but the effect size was greater for negative pictures only. The Main effect of Cue F(1, 27) = .934, p = .340, *η2p* = .034, and the interactions involving any of the other factors did not reach significance, Cue × Valence × Memory × Anteriority × Laterality F(2, 54) = .678, p = .486, η^2_p = .018. Overall these results show evidence of a Dm effect after the picture onset but without any topographical differences.

5.4.3.2 Picture-related early peak analysis

Early ERP components for the post-stimulus phase were investigated to detect the effect of anticipation on amplitudes of attention-related ERP components, i.e., P1, N1, P2, and N2 components elicited by the picture stimulus. The main focus is on cue and valence-related factors.

5.4.3.3 50-100ms positive peak: P1

Cue-related significant differences were observed at Cz, $F(1, 27) = 6.51$, $p = .017$, η2p = .194 electrode sites where mean amplitudes elicited more negative-going potential for the No-Cue condition (M = -1.46,-1.19, SE = .320, 297) compared to the Info-Cue (M = -1.89,-1.76, SE = .315,.319). For Pz $F(1, 27) = 5.38$, $p = .023$, η2p = .178 a positivity was found for the No-Cue (M = .551, SE = .328) compared to the Info-Cue (M = .048, SE = .317) condition. During this time window, a main effect of Valence was observed at O1 $F(1, 27) = 6.52$, $p = .017$, η2p = .195 eliciting higher positivity for the Info-Cue (M = 2.60, SE = .452) than No-Cue (M = 2.14, SE = .511) condition. The Cue × Memory interaction was also significant $F(1, 27) = 5.72$, $p = .024$, η2p = .175. This interaction was split by valence and revealed a significant effect of memory for the Info-Cue $F(1, 27) = 3.84$, $p = .060$, η2p = .125, but not for the No-Cue condition $F(1, 27) = 1.49$, $p = .232$, η2p = .052. Mean scores showed a higher positive-going amplitude for the remembered items (M = 5.026, SE = 1.05) than for the forgotten ones (M = 3.99, SE = 1.04).

5.4.3.4 100-150 ms negative peak: N1

No significant main effect for Valence was observed over Cz, $F(1, 27) = 1.24$, $p = .275$, η2p = .044, Fz, $F(1, 27) = 1.722$, $p = .201$, η2p = .060 and Oz, $F(1, 27) = .337$, $p = .567$, η2p = .012 in this time window.

5.4.3.5 150-200 ms positive peak: P2

At the Pz electrode site, there was a significant main effect for Cue $F(1, 27) = 5.26$, $p = .030$, η2p = .163, with No-Cue showing more positivity (M = 1.313, SE = .643) than Info-Cue (M = 2.093, SE = .696). Valence effect was also significant $F(1, 27) = 6.43$, $p = .017$, η2p = .193 with an overall positivity for the negative pictures (M = 2.114, SE = .723) greater than for neutral ones (M = 1.192, SE = .631). The main effect of Memory was also significant $F(1, 27) = 4.40$, $p = .045$, η2p = .140 such that the remembered items (M = 1.94, SE = .680) showed higher amplitude than forgotten ones (M = 1.45, SE = .636). However, no interaction was significant involving any of these factors (F's < .137, p's > .251).

5.4.3.6 200-300 ms negative peak: N2

No significant main effects or interactions were found to be significant for emotional memory, nor for the effect of anticipation on the visually-evoked potential (F's < .137, p's > .251).

5.4.3.7 300-400 ms positive peak: P300

A repeated measures ANOVA at the Cz electrode site revealed a main effect for Cue $F(1, 27) = 8.02$, $p = .009$, η2p = .229 with Info-Cue condition showing more negativity (M = -1.51, SE = .711) than the No-Cue condition (M = -.537, SE = .680). The main effect of Valence $F(1, 27) = 49.67$, $p = .001$, $\eta 2p = .648$ was significant with greater positivity for negative pictures (M = .041, SE = .703) than for neutral pictures (M = -2.09, SE = .676). A significant interaction was also found for Cue × Valence $F(1, 27) = 4.05$, $p = .054$, $\eta 2p = .130$. Simple effect analysis revealed a significant Valence effect across both cue conditions $Fs (1, 27) \geq 10.36$, but the effect size was greater for the Info-Cue ($\eta 2p = .591$) compared to the No-Cue ($\eta 2p = .277$) condition.

5.5 Discussion

The focus of the current experiment was to investigate the electrophysiological basis of anticipation of emotional memory and its comparison with the No-Cue (non-anticipation) condition. Findings revealed no ERP-related differences between the Info-Cue and No-Cue conditions. These results are consistent with the prediction of the current experiment that the memory-related ERP captured previously at the pre-stimulus phase does not represent a memory component, but is rather just random fluctuations or noise. The post-anticipation phase Dm effect, however, was significant but without any region or laterality effects. Behavioral findings were also non-significant. This section discusses the predictions of cue-locked and picture-locked ERPs followed by an explanation of the behavioral findings.

5.5.1 Ps-Dm effect during anticipatory phase

The main prediction was related to the detection of the Ps-Dm effect during the Info-Cue condition (anticipatory phase). For a reliable Ps-Dm effect, it was expected to find a difference in the amplitude of remembered and forgotten waveforms for the negative pictures presented with Informative cues during the anticipatory phase. However, a reliable memory effect associated with the anticipation of negative pictures anticipation was not elicited under this condition. Findings revealed two significant interactions for informative cues: One anticipation of negative picture elicited more positive going waveform at midline scalp site compared to neutral picture but only for informative cue during 350-600ms time window. This interaction was observed without memory effects. These findings suggested that when participants are aware of the valence of upcoming pictures, it helps them prepare for encoding of negative as well as neutral pictures. Predictions that only negatively-valence anticipatory process help in facilitating memory at the anticipatory phase could not be validated by the findings of the current study. However, reverse effect of cue were observed when data was analyzed for sustained anticipation period only, i.e., 1000-3000ms with a new baseline (-1200ms) by excluding neural activity related to presence and absence of cues. It was observed that cue related difference for valence were more pronounced for No-Cue condition than Informative cue condition.

Second significant interaction involved a difference in remembered and forgotten waveforms for informative cue only regardless of the valence. This interaction was significant for both anticipatory phases: ~400-1000ms and 1000-3000ms. These findings suggest that anticipation facilitates encoding of negative and neutral pictures equally well. Moreover, these findings showed no difference in the results for both time windows which differ with respect to the cue display on the screen. Based on the literature on cortical measures of anticipation, the anticipatory phase was sub-divided into two longer time windows: ~0-1000ms time window when the cue was on the screen and 1000-3000ms when the cue disappears. This distinction was made to rule out the possibility if Ps-Dm effect is specific to the persistent display of the cue on screen or to the sustained anticipatory attention after the cue disappears. It might help making a more precise conclusion about the Ps-Dm effect in any one of the time windows. Thus far, findings revealed no difference on this basis. These findings are in contrast to the studies which found a significant memory effect for negative pictures only presented with informative cues and proposed a preparatory process explanation for their findings (Galli et al., 2014; Galli, Wolpe, et al., 2011; Mackiewicz, Sarinopoulos, Cleven, & Nitschke, 2006a; Nitschke et al., 2009).

The main manipulation in the experiment was the presence and absence of cues. It was expected that absence of cues would be related to uncertainty, which would provide an emotional context for the encoding of emotional information. Therefore, if the Ps-Dm effect were to appear for this condition, that might be driven by emotional arousal at the pre-stimulus phase due to uncertainty. However, the non-significant Ps-Dm effect for this condition showed no support for this prediction. Another related prediction in this experiment was that participants would evaluate aversive stimuli as even more aversive than the negative pictures in the Info-Cue condition. To this extent, findings of the SAM valence-rating study appeared to support the contention that uncertainty provided an emotionally negative context. Under the influence of this context, participants' valence ratings to low arousal negative stimuli were greater in the No-Cue condition. These findings are in line with many studies where temporal unpredictability produced an anxiety-like behavior in mice and was accompanied by enhanced spatial attention to emotional face expressions (Herry et al., 2007) and greater sensitivity to unanticipated stimuli in females (Jin et al., 2013). Despite behavioral evidence suggesting an emotional context at work here, it did not enhance encoding of emotional images.

So, taken together, the non-significant memory difference in the waveform for the negative pictures in the anticipation phase for Info-Cue and No-Cue Condition suggest that neither the preparatory process hypothesis nor arousal due to uncertainty accounts for differences between the factors. However, these findings could lead towards initial evidence in favor of the random fluctuation hypothesis proposed as an alternative explanation for the Ps-Dm effect at the anticipatory phase. However, before reaching this conclusion, there are certainly other issues concerning the phenomenon which need to be discussed.

In the electrophysiological literature on anticipation, the focus has been on cue-related cortical processing at the earlier time window, starting from ~0-1000 ms. An important finding in this time window was a P300 component. A significant emotional effect that is more positive-going deflection for negative stimuli than for neutral stimuli was observed at the midline posterior site for Info-Cues during the (P3: 350-650ms) time window. These findings suggest that rather than cues being processed merely as a presence of upper case letters, they were processed with the perceptual meaning (valence) embedded in cues. These findings are further consistent with an account related to P300, which is that it is considered an indigenous ERP component elicited from 300-600ms after stimulus onset and maximal at midline parietal sites (Almasy et al., 2001; Begleiter et al.,1998). The cortical differences in this earlier time window were more related to the properties of the cue. An important point to consider is that the cue-related main effect remained significant from the (P2: 200-350ms) (P3: 350-650ms) time windows, but it gradually decreased and then diminished in the (700-800ms) time window. In sum, these findings suggest that the cue-related emotional effect did not continue over time during sustained anticipatory responses in the later time window.

5.5.2 Emotional anticipation: SPN

Another prediction was made for Stimulus-Preceding Negativity (SPN), which is interpreted as a physiological index for the anticipation of emotionally significant stimuli. A 2800-3000ms time window was examined to capture SPN. It was expected that if emotional anticipation is at work, then just 200ms before the onset of S2 (emotional pictures), the waveform corresponding to the anticipation of negative pictures would be different from the waveforms of the neutral picture. The findings revealed a non-significant SPN effect which implies that emotional anticipation was not at work. These results corroborate well the findings reported above for 1000-3000ms time window where no valence-specific memory differences were found. The negative and neutral pictures were encoding equally well for the Informative cue condition in that time window. However, these findings are inconsistent with studies which have found a strong SPN effect just before the onset of pictures (Bocker, Baas, Kenemans, & Verbaten, 2001; Böcker, Baas, Kenemans, & Verbaten, 2001; Buodo et al., 2012). It is plausible that the largest cortical negativity during emotional anticipation is only linked to high-arousal negative pictures (P2) (Buodo et al., 2012; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007; Porro et al., 2002).

Nevertheless, there are two potential justifications for the non-significant SPN effect: first, in the current experiment, an equal number of high and low arousal negative pictures were used which were not perceived as emotionally strong as required for a reliable Ps-Dm effect for the encoding of a negative picture, and for a significant SPN component. This conclusion is further supported by the current behavioral data; i.e. SAM valence rating analysis compared across cue conditions. It was found that participants rated high arousal emotionally negative pictures as less arousing when they were aware of the valence of upcoming pictures as compared to the condition when they were not told what picture would come next. Moreover, these findings are further supported by the finding that anticipating a more painful stimuli reduced the level of arousal in the subject once the stimuli were presented (Koyama et al., 2005).

Taken together these findings suggest that participants did not perceive the upcoming negative pictures as emotionally arousing as would be enough to process and to encode them.

5.5.3 Picture-related subsequent memory effects

Picture-locked ERP analyses were conducted to find two pieces of information. First, whether or not a classic Dm effect will emerge, as in a previous study (Galli, Wolpe & Otten, 2011) which did not find valence-specific memory differences at the post-stimulus phase. Second, analysis aimed at investigating whether anticipation modulated early ERP components at the post-stimulus phase. Results were mixed and could not yield a clear picture. P1 amplitudes were found to be higher for those pictures that were processed with cues at the frontal electrode (Fz). In contrast, at the parietal region (Pz) reverse effects were seen, i.e., the amplitude for the unanticipated trials was higher than for cue-related trials. However, higher amplitude was found for the same component at the O1 site for emotional pictures. These findings are consistent with an ERP study which found these effects to be reliable for an emotionally-cued task in contrast to a semantic one (Padovani et al., 2011). Together, these results suggest that anticipation influences attention at the start of the post-stimulus epoch. The other ERP components studied in this context were N1 (Padovani et al., 2011) and N2 (Onoda et al., 2006) at the occipital region. No difference was found related to cue condition or valence for these two components. These results are supported by an MEG study that investigated the modulatory effects of anticipation on the visually-evoked magnetic field (VEF). Their findings showed a smaller amplitude for M120

(MEG counterpart of N2: visually evoked potential) when subjects anticipated a negative image before the event. Moreover, just like our findings, VEF amplitudes did not differ from those of No-Cue Negative conditions; the amplitude of the P3 component was modulated by anticipation, which may indicate that subjects paid more attention to the pictures when presented with emotional cues.

Picture-related ERP analysis reveals a well-documented subsequent memory effect overall (Cunningham et al., 2014; Kiefer, Schuch, Schenck, & Fiedler, 2007; Kim, 2011; Murty, Ritchey, Adcock, & LaBar, 2010; Otten, Henson, & Rugg, 2001; Righi et al., 2012) which signifies that emotionally negative pictures are processed in priority, and has an effect on memory encoding. However, these Dm-effects were found regardless of the effects of cue conditions or region, or laterality difference.

5.5.4 Behavioral data

Although the main focus of this experiment was on ERP analysis, behavioural data was also corrected for recognition memory, SAM valence rating difference across cue conditions, and reaction time analysis for SAM valence rating tasks. Behavioural findings showed an enhancement of recognition memory accuracy for negative pictures compared to neutral without the influence of cue type. These findings are inconsistent with the behavioural experiment reported in Chapter 4 which demonstrated that the subject’s memory performance was modulated by informative and Non-Informative cue conditions but not by No-Cue condition.

5.6 Conclusions

In conclusion, the findings of the current study demonstrate that anticipation of upcoming negative pictures does not enhance emotional memory performance at the behavioral level. At a physiological level, findings revealed that informative cues modulated memory but regardless of the valence of the picture. It implies that no evidence was found for the Ps-Dm effects for negative pictures during the anticipatory phase. For the post-stimulus phase, subsequent memory effects for emotional memory were found but without any difference pertaining to scalp region and laterality. Anticipation did not appear to modulate subsequent memory at the post-stimulus phase either.

5.7 Future directions

There are certain limitations to this study. For instance, Non-Informative cues could not be included in this experiment because of the reason that it requires an additional set of 200 IAPS pictures, which might result from a very lengthy experiment. A lengthy experiment might lead to fatigue and boredom on the part of participants; moreover, it may also cause the drying of EEG gel in the electrodes. Therefore, the next study focused on exploring the role of anticipation in non-informative cues in comparison to fully informative cues. These Non-Informative cues were predictable in time but provided no specific information about the valence of the cues.

Chapter 6: Pre-stimulus subsequent memory effects for informative and non-informative cues

6.1 Overview

The behavioural study reported in chapter 4 showed an emotional memory enhancement effect for informative and non-informative cues but not for No-Cue condition. However, the findings were limited to the behavioural effect. What happened at the neurological level at the anticipatory phase was out of the scope of that study? The current event-related potential (ERP) study was designed to investigate the electrophysiological evidence of the effect obtained in the previous behavioural study. Therefore, the objective of the study was to find Pre-stimulus (Ps) Dm effects at anticipatory phase for Informative as well for Non-Informative cue conditions. Findings revealed a memory effect but for neutral stimuli instead for emotionally negative for both cue types. However, there were latency related differences that was for Non-Informative cues, the difference between the amplitude of remembered neutral and forgotten was elicited with a more positive-going deflection at midline anterior scalp site during the 600-800-time window. In contrast, for Informative cues this memory effect for neutral picture anticipation was observed in the later time window (1000-3000ms) without any scalp distribution. The justifications of the current findings, limitation and future experiment have been discussed further in the chapter.

6.2 Introduction

The anticipation of future events is a central function of the nervous system (Mossbridge, Tressoldi, & Utts, 2012). In normal healthy individuals, information about an impending dangerous situation activates preparatory processes which enable them to maintain safety. For instance, the ringing of the smoke alarm signals fire and prepares the individual for escape. However, in many everyday situations our knowledge of impending danger is limited. Lack of specific information about future events makes the environment unpredictable, and unpredictability leads to worry, anxiety, and mal-adaptiveness (Dugas et al. 1998; Barlow, 2002; Lohr et al. 2007; Krain et al., 2008; Simmons et al., 2008). Studies have found that an enhanced neural response during anticipation of an event is associated with the successful remembering of that event in the future (Galli, Wolpe, & Otten, 2011; Mackiewicz, Sarinopoulos, Cleven, & Nitschke, 2006). However, the mechanism behind this enhanced memory is not clear yet. More specifically, it is unknown whether mental readiness regarding the encoding of aversive events leads to enhanced memory, or whether it is the random fluctuation in attention which enhances memory when information about the picture valence is lacking. This question is the main focus of the current experiment.

In study 2 (chapter 5) of this thesis, the absence and presence of the cue were manipulated to see if the presence of a cue plays a role in the Ps-Dm effect. Findings revealed that cue presence only mattered during the cue presentation; however, the sustained anticipatory responses to the anticipation of an emotional memory were not found in the later time window. In the current experiment, the information content of cues regarding the valence of the upcoming pictures (informative vs. non-informative) was manipulated. The informative cue (Info-Cue) and non-informative cue (Non-Info Cue) conditions involved the same set of anticipated pictures but differed in that the Info-Cue trials provided an opportunity for anticipatory goal preparation that was specific to the valence of the picture (or S-R rule activation). In contrast, this was not the case in Non-Info cue trials, where participants had no specific goals regarding the anticipation of the event and no preparation specific to the type of picture (negative or neutral). The Non-Info cue condition was manipulated to investigate whether Ps-Dm effects are relatively independent of task preparation. This idea came from an unrelated memory experiment conducted in Schaefer's lab (Yick, Buratto and Schaefer, 2015). During exploratory data analysis of the study, a Ps-Dm effect was found for negative pictures in the absence of non-specific preparatory cues. The findings were intriguing in the sense that, unlike Galli et al.'s (2011) informative cues, only a "+" cue sign was presented before each trial, which lacked information about the nature of the upcoming stimuli. This raised the possibility that the observed Ps-Dm effects might have been caused by random fluctuations, rather than some preparatory process at work. Taken together, these lines of evidence provide a contextual framework for the determination of electrophysiological correlates of anticipation and emotional memory.

A number of non-ERP studies provide examples of the efficient processing of emotional stimuli under non-informative and no-cue conditions (Onoda et al., 2006). Power/spectral EEG studies (investigation of different frequency bands) have successfully predicted and analysed pre-stimulus subsequent memory effects without any informative cue (Fell et al., 2011; Guderian, Schott, Richardson-Klavehn, & Düzel, 2009; Noh, Herzmann, Curran, & de Sa, 2014). Fell et al. (2011) found higher theta activity in an intracranial EEG study during the pre-stimulus phase in the rhinal cortex and hippocampus - an important region regarding memory formation. In an MEG study, Guderian et al. (2009) observed stronger pre-stimulus power effects for later-remembered words in theta 3-8 Hz 200ms before item presentation. In contrast, Noh et al. (2014), conducted a single-trial ERP analysis and found a pre- and post-stimulus subsequent memory effect around 25-35 Hz in the 300ms time interval before the second stimuli display and in the 1000-1400ms time interval for the post-stimulus effect. However, this effect was limited to neutral stimuli, such as pictures of birds and cars. Single-trial EEG analysis is different than ERP in that it considers the variability within subjects and provides additional information which is not observable when data is collapsed across conditions and trials (Pernet, Sajda, & Rousselet, 2011). Taken together, the findings from the oscillatory and sustained ERP studies raise the possibility that the pre-stimulus effects reported by Galli et al. (2011) might be found even when the cues are non-informative, depending on the motivational significance of the emotional event for the individuals.

Preparatory processes facilitate memory during anticipation when participants know whether a negative or neutral picture is coming up (Cahill et al., 2001; Galli, Wolpe, et al., 2011; Mackiewicz et al., 2006b). However, the mechanism behind the Ps-Dm effect for Non-Info cues, where participants don't know specifically about the valence of the imminent pictures, is not yet clear. From an evolutionary perspective, it would be a highly adaptive skill if individuals could somehow get themselves prepared for important imminent events either by activating the sympathetic nervous system or other brain regions in the absence of perceptual or physical cues (Mossbridge et al., 2014a). No ERP study so far has tested memory advantage for the Non-Info cue condition. Moreover, an investigation into the mechanism behind pre-stimulus activity during Non-Info is only available in a handful of recently published articles. One such attempt was made by Mossbridge et al. (2012), who conducted a comprehensive meta-analysis of 26 studies (published between 1978-2010) that found significant pre-stimulus effects using fMRI, ERP, pupil dilation, and electrodermal activity measures in the absence of cues or anticipation. The review suggested that the direction of pre-stimulus activity is predictive of post-stimulus activity, even when the imminent stimulus itself is unpredictable. In a very recent review paper, Mossbridge et al. (2014) termed it as "predictive anticipatory activity (PAA)". In the previous study (Chapter 5) and in the present study, the random fluctuation hypothesis, which has been proposed as an explanation for the Ps-Dm effect in the case of Non-Info cues, appear similar to the concept of PAA. Specifically, the random fluctuation hypothesis proposes that the observed memory-related ERP activity is a just random fluctuation or artefacts and not an index of ERP component such as Dm effect

Predictive anticipatory activity (PAA) refers to statistically reliable differences between physiological measures recorded seconds before the occurrence of an unpredictable emotional or neutral event (Mossbridge et al., 2014). PAA by definition, captures three mechanisms, such as the prediction of random future events, the anticipation of emotional/neutral events occurring greater than chance, and the physiological activity of the autonomic and central nervous system. Mossbridge et al. (2014) postulated that PAA is an unconscious physiological phenomenon which might be viewed as the preview of conscious awareness of upcoming emotional and arousing events (Mossbridge et al., 2014).

The Ps-Dm effect for the Non-info cue condition might be explained in terms of the modulation hypothesis. Lack of information or uncertainty about the upcoming picture's valence was shown to activate brain regions which were also involved in emotional processing (Herwig, Kaffenberger, Baumgartner, & Jäncke, 2007). It has been observed that dorsolateral and inferior prefrontal cortex, orbitofrontal cortex, cingulate gyrus, insula, amygdala, thalamus, midbrain and parietal-occipital areas are activated while expecting stimuli with unknown valence. In their ERP study, Jin et al. (2013) found gender differences in the P2 component during the non-informative cue condition, suggesting that females allocated more attentional resources to detect unexpected stimuli when the valence of the picture was not known, as compared to the predictable valence of pictures. In light of these studies, we might speculate that the Non-Info cue condition, in which valence is unpredictable, might provide an emotional context for the individual and, therefore, induce a certain level of arousal relative to a condition where valence is known. Manipulation of the Non-Info cue condition would allow us to see if physiological arousal might influence the Ps-Dm effect.

One salient feature of the human neural system is the presence of ongoing spontaneous variability (Cohen & Maunsell, 2011; Nir et al., 2008; Romei et al., 2008). There is a possibility that spontaneous neural fluctuations in attention predict the decision to attend during Non-Info cue conditions. Neural variability influences many cognitive functions such as memory, decision making (Bengson, Kelley, Zhang, Wang, & Mangun, 2014; Brunton, Botvinick, & Brody, 2013), memory retrieval success (Addante, Watrous, Yonelinas, Ekstrom, & Ranganath, 2011) and efficacy of control functions (Bengson, Mangun, & Mazaheri, 2012). However, it might be speculated that neural fluctuations influence memory-related neural activity at the pre-stimulus phase.

The Stimulus-Preceding Negativity (SPN) component has been extensively studied with respect to expectancy and emotional anticipation a few milliseconds before the onset of the picture stimuli (Böcker, Baas, Kenemans, & Verbaten, 2001; Brunia, 1988; Buodo et al., 2012; Catena et al., 2012; Chwilla & Brunia, 1991; Hillman, Apparies, & Hatfield, 2000; Takeuchi, Mochizuki, Masaki, Takasawa, & Yamazaki, 2005; Van Boxtel & Böcker, 2004). However, findings by Catena et al (2012) postulated that the SPN appears to be linked to control-related areas in the prefrontal cortex that become more active before the occurrence of an uncertain upcoming event (Catena et al., 2012). These findings suggest the possibility of the presence of the SPN even in cases of unpredictable stimuli. There appears to be inconsistency in the literature regarding SPN for predictable and unpredictable stimuli. In the current experiment, without making directional hypotheses, SPN is explored in the Info-Cue condition as well as in the Non-Info cue condition.

Thus far, available explanations for the Ps-Dm effect for emotional stimuli (ERP: Giulia Galli et al., 2011) and for neutral material (fMRI: Bollinger et al., 2010) point to the role of preparatory processes at work, which enhance emotional memory. Current evidence for the role of anticipation processes is restricted to memory formation in the presence of an opportunity to prepare for the event (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006; Otten, Quayle, Akram, Ditewig, & Rugg, 2006). It is still unknown how the Ps-Dm effect is influenced when participants are devoid of preparation for the upcoming stimuli. In spite of little evidence of memory formation at the anticipatory phase in response to the informative cues, the mechanism that drives this effect is debatable, considering the methodology and explanation. For instance, the use of emotional pictorial stimuli as cues, and the presence of cues on the screen for the whole duration of anticipation, suggest that pre- and post-stimulus processes are dissociable.

Evidence and explanation for the Ps-Dm effect come from studies which differ in the techniques used to explore this concept. For instance, one source of evidence for the Ps-Dm effect comes from an fMRI study, in which only high-arousal negative pictures were used as S2 (Mackiewicz, Sarinopoulos, Cleven, Nitschke, & McGaugh, 2006), and cues were symbolic. In this study, data were analyzed according to the arousal rating by subjects. Ps-Dm effects have also been reported in power spectral studies where the methods of analysis are different from the ERP-related analysis (Ergenoglu et al., 2004; Fell et al., 2011; Gärtner & Bajbouj, 2014; Hanslmayr, Spitzer, & Bäuml, 2009) and hence incomparable. Thus, it remains speculative as to what mechanisms facilitate encoding-related ERP differences under anticipatory situations. The Ps-Dm effect has only been found with informative cues without manipulating the informational content of the cue. Although these studies shed some light on the electrophysiological correlates of pre-stimulus neural activity, which predict EEM, they do not explain the functional meaning of these patterns. That is to say, they do not identify the cognitive mechanisms that are at work, which underlie these neural patterns of activity and consequently lead to the EEM phenomenon.

Evidence for the Ps-Dm effect gathered in the absence of information about the imminent aversive images further complicates the understanding of this effect. Whether the Ps-Dm effect that occurs in response to anticipatory cues reflects a real ERP component related to memory (G Galli, Bauch, & Gruber, 2011; Giulia Galli et al., 2011), or instead merely represents random fluctuations in attention (Yick, Buratto & Schaefer, 2015; Mossbridge et al., 2014) is the focus of the current experiment.

6.2.1 Role of attention in short and long-term memory formation

Another explanation for the Ps-Dm effect regards the role of attention, which prepares individuals for attending to specific stimuli before they appear (Bollinger, Rubens, Zanto, & Gazzaley, 2010). Preparatory attention is an integral part of anticipatory processes (Fernández & Siéroff, 2014), and contrary to selective and brief attention is a slow process working over a range of seconds, which involves an enhancement of attention to particular stimuli before the are expected to occur. (Fernández & Siéroff, 2014; LaBerge, 2005). In other words, preparatory attention is a deliberate, conscious mechanism through which attention is selectively given to stimuli. The attention capture hypothesis has been tested for visual-spatial working memory formation by Schmidt, Vogel, Woodman & Luck (2002). They found evidence of the transfer of perceptual representations into visual working memory for both temporally predictive and non-predictive cues. Evolutionary explanations account for enhanced attention allocation towards anticipation of the upcoming stimuli in the absence (Jin et al., 2013) and presence (Giulia Galli et al., 2011) of information about the upcoming aversive situation.

6.2.2 Anticipation and efficient processing

If an individual is fully and specifically informed about what is going to happen next, his/her response to a subsequent task is quick and efficient. This phenomenon has been studied extensively in task switching paradigms, which show that anticipatory cues help individuals prepare for the task switching, and results in a higher "switch cost', i.e., longer reaction times (Karayanidis et al., 2009; Kieffaber & Hetrick, 2005). However, it has also been observed that despite longer cue-to-target time intervals, which provide ample time for the preparation of task switching, there remains a switch cost, referred to as a 'residual cost'. There are two models which provide an account for this residual switch cost for informatively cued trials: The cognitive control model and the S-R retrieval model. According to the cognitive control hypothesis, processes responsible for switch cost lie at the pre-stimulus phase, where a failure of effective anticipatory processes results in longer reaction times. In other words, the anticipatory/preparatory process is not fully engaging or active, and hence its failure causes a residual switch cost. Active and engaging anticipatory processes depend on the probabilistic nature of the cue or relevant motivational factors for the upcoming task (De Jong, 2000; Gladwin, Lindsen, & De Jong, 2006; Nieuwenhuis &

Monsell, 2002). The second hypothesis emphasizes that processes responsible for switch cost lie at the post-stimulus phase, where a proactive inhibition from the previous task results in a longer reaction time. Therefore, switch cost is stimulus-dependent (Finke, Escera, & Barceló, 2012; Jamadar, Hughes, Fulham, Michie, & Karayanidis, 2010; Sohn, Ursu, Anderson, Stenger, & Carter, 2000). A quick reaction to the anticipated negative trials would provide support for the preparatory process hypothesis and indirectly would play a role in explaining the Ps-Dm effect advantage during the pre-stimulus phase. In the current experiment, an attempt has been made to relate the findings to the models proposed, as an account for the switch cost in informative trials.

6.2.3 Rationale and aims

The experimental design and hypothesis of this study are guided by the theoretical rationale provided in the introduction section. As in the previous study, the Ps-Dm effect is investigated in instant and sustained anticipatory responses to cues by dividing the anticipatory phase into early and late time windows. The following predictions are made:

(i) As in the Study 2, the Ps-Dm effect is expected to be found during the cue display period (0-1000ms), as Galli et al. (2011) found it for the period of cue display.

(ii) A reliable Stimulus-preceding Negativity (SPN) is expected in the late time window (2800-3000ms), which is an indicator of affective anticipation during the Info-Cue condition.

(iii) A Ps-Dm effect is expected for the Non-Info cue condition, which might indicate that memory is independent of preparatory processes during anticipation.

(iv) Picture-related early ERP components such as P1, N1, P2, N2, and P300 will be influenced by the Info-Cue condition.

(v) At the behavioural level, faster reaction times are expected for the Info-Cue condition as a function of enhanced processing of emotional stimuli.

(vi) The Non-Info cue condition induces uncertainty, which in turn causes arousal (Herry et al., 2007). In this context, at the behavioural level, it is predicted that participants will rate negative pictures more negative as compared to negative pictures rated in the informative cue condition.

6.3 Method

6.3.1 Participants

Forty-three healthy female participants (mean age = 20.31 years, SD = 3.4 years) were recruited from the Durham university undergraduate participant pool and from the surrounding community. They were remunerated £25 for their participation or received participant pool credits. Participants' characteristics, recruiting criteria and screening procedure, were the same as mentioned in chapter 5 section 5.3.1.

Fifteen of the participants were excluded from the sample either because: their memory scores fell above 3SD from the sample mean; their memory performance was less than 12 trials in all relevant experimental conditions; because of persistent muscle artefacts in the EEG signal; frequent eye blinking; or high impedances levels. Participants with fewer than 12 artefact-free trials were excluded from the analysis. This criterion is in line with many previous ERP studies on memory processes (Giulia Galli et al., 2011; Gruber & Otten, 2010; Padovani, Koenig, Brandeis, & Perrig, 2011; Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014).

Table 6.1: Number of participants excluded from the data analysis with identity code and reasons for exclusion

Total Removed	Codes	Reasons for removal
5	8, 20, 23, 24, 32	These files were excluded for two reasons, one, their memory scores fall above 3SD from the sample mean, second, their memory performance was less than 12 trials in all the relevant experimental conditions.
10	3, 4, 5, 6, 9, 18, 26, 30, 31, 37,	These files were not included because of Persistent muscle artefacts in EEG signal or frequent eyes blinking or high impedances level.

The mean age of the final 29 female participants was 20.6 years, (*SD* = 2.19). On average their scores fell within the normal range on all the subscales of the DASS, (Depression, X = 2.70, SD= 4.32; Anxiety, X = 2.53, SD= 5.50 and Stress, X= 4.17, SD = 4.08).

6.3.2 Design

A repeated measures experimental design was employed. In comparison to Study 1 where the Info-Cue condition was paired with the controlled (cue absent) condition, the informative nature of the cue was manipulated. The main contrast involved informative (Info-Cue) verses non-informative (Non-Info) cues. Info-Cues (X = negative; O = Neutral) informed participants of the valence (emotionality: negative or neutral) of the upcoming pictures (Info-Cue condition) while the non-informative cues (Z) provided no specific information about the subsequent pictures' emotional content (Non-Info condition). The probability of the occurrence of an emotional picture was 50% in the Non-Info condition.

6.3.3 Stimuli and Material

The letters X, O, and Z were used as symbolic cues for the informative-negative, informative-neutral and non-informative cue conditions respectively for the pre-stimulus phase. For the post-stimulus phase, the pictures used were the same set used in Experiment 1 from the International Affective Picture System (IAPS). However, the division of the number of pictures into conditions was different. The selected set of 560 IAPS pictures was first split into 400 (Negative = 200; Neutral = 200) and 160 (Negative = 80; Neutral = 80) picture sets to be used for the encoding and retrieval phases of the experiment, respectively. In the study phase, an equal number of negative and neutral pictures were presented under informative and non-informative cue conditions. Twelve pictures were selected separately for the practice phase.

Cue conditions were presented separately in 4 blocks. Equal numbers of high and low arousal negative and neutral pictures were included in each block. A short rest break was given after each block. To avoid any memory bias in the study phase, the negative and neutral pictures were presented with the constraint that no more than two consecutive trials presented the same stimulus valence. The old-new status of the negative and neutral pictures and block order were counterbalanced across participants. EEG was recorded for the study phase only.

The test phase consisted of a total 560 images, 400 old pictures, and 160 new pictures (80 negative and 80 Neutral). Info-Cue and Non-Info cue trials were presented randomly in each block. Therefore, in the test phase, only the order of the blocks was counterbalanced across participants.

6.3.4 Procedure

Participants were seated in a comfortable position, approximately 70cm away from the 19" computer screen. Prior to the main experiment, participants went through the instruction phase, where they were provided with the training to learn to associate each cue to the corresponding picture type. Details of the hardware used in the experimental procedure are same as given in chapter 5, see section 5.3.4 on page 112.

6.3.4.1 Study/Encoding phase

Event-related potentials were recorded only for the encoding phase. A visual illustration of the sequence of events is given in Figure 6.1 below:

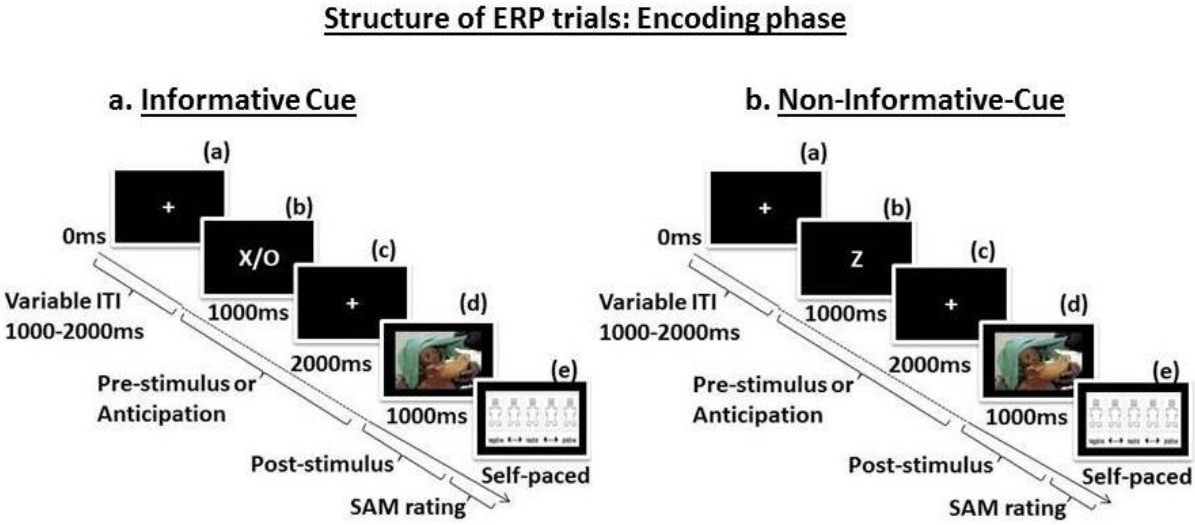


Figure 6.1: Encoding phase- Schematic of the Experimental Trial

a) Each trial started with a fixation sign (+). Duration was 100ms, which varied randomly in a jitter manner between 1000-2000ms.

b) Participants were presented with cues (X, O, and Z) which remained on the screen for 1000ms only.

c) A fixation sign then appeared on the screen for 2000ms, until the end of the epoch at 3000ms.

d) Pictures were displayed on the screen for 1000ms as a post-stimulus.

e) Participants rated the valence of the each picture after its display, using a five-point rating scale (SAM). The rating task was self-paced.

The cue display time duration was kept as 1000ms, and in Study 2 it was 500ms. In the previous study, it was chosen to make the No-cue condition unpredictable in time and to reduce the length of experimental trials. However, overall the time duration of the cue to the picture was the same; 3000ms in both experiments.

6.3.4.2 Test/ Retrieval Phase

The instructions, tasks, and trial procedure of test/retrieval phase of this experiment were the same as given in chapter 5, section 5.3.4.2 (page 113).

6.3.5 Electrophysiological Data Recording and Processing

ERP data recording and processing were the same as chapter 5, section 5.3.5 (page 115).

ERP waveforms were created using averaged EEG data for remembered and forgotten trials, for negative and neutral Info-Cue and Non-Info cue conditions, such as Info-negative-remembered, Info-negative-forgotten, Info-neutral-remembered, Info-neutral-forgotten, Non-Info-negative-remembered, Non-Info-negative-forgotten, Non-Info-neutral-remembered, Non-Info-neutral-forgotten. The mean number of artefact-free trials of foregoing conditions is given as follows: 34.02, 20.23, 22.36, 30.30, 31.72, 20.45, 24.57, 26.54, respectively. Participants with fewer than 12 artefact-free trials were excluded from analysis. This criterion has been adopted for the second study and the current one, in line with many previous ERP studies on memory processes (Galli et al., 2011; Gruber & Otten, 2010; Padovani, Koenig, Brandeis, & Perrig, 2011; Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014).

6.3.6 Electrode clusters

Same as described in section 5.3.6 chapter 5 (page 115)

6.3.7 Picture-Locked ERP time bins

Same as described in section 5.3.7 chapter 5 (page 116)

6.3.8 Cue-Locked ERP time bins

Time bins selected for the cue-locked analysis were different from the time bins selected in Study 2 chapter 5, due to the modification in design and to meet the requirements of this experiment. The time windows were selected on the basis of careful visual inspection and considering the literature on anticipatory related activity. The epoch duration for the anticipatory phase was 3000ms. For analysis purposes, the activity was divided into two phases of time, i.e., 0-1000ms and 1000-3000ms for capturing Ps-Dm effects.

To investigate the development of memory formation over time during the 400-1000ms time bin, mean amplitudes were extracted from the 3 sub-time windows (400-600ms), (600-800ms), (800-1000ms). It was predicted that subsequent memory effects for emotional images would be more pronounced over anterior sites, with remembered being a more negative-going waveform compared to forgotten under informative cue condition (Galli et al., 2011). For the Non-Informative cue condition, it was expected to find similar Ps-Dm effects over the same scalp region, which would support the random fluctuation hypothesis. Because of the lack of relevant literature on this aspect, no specific prediction for a time window and scalp region were made.

6.3.9 Reaction Time Analysis

Anticipation facilitates efficient processing of information. A number of studies available on attention capture have focused on reaction times as measures of superior cognitive processing (Bollinger, Rubens, Zanto, & Gazzaley, 2010; Schmidt, Vogel, Woodman, & Luck, 2002). This analysis was conducted to test if the reaction times on the SAM rating task are modulated by anticipation. Specifically, a faster rating time was expected for Info-Cue conditions than for Non-Info cue conditions.

6.3.10 Statistical Analysis

Analysis for each time window selected for pre-stimulus and post-stimulus effects, repeated measures ANOVAs were computed on mean amplitude including the following factors: Valence (Negative vs. Neutral Cues/Pictures), Cues (Informative Vs. Non-Informative) Memory (Remembered vs. Forgotten), Location (Anterior vs. Posterior), and Laterality (Left vs. Right vs. Midline). For conciseness, and given the focus on the Dm effect, the memory factor effects were preferentially targeted. Given that the experimental hypothesis suggests that Dm activity should be observable in the non-informative cue condition, the main expectation was to find a statistical effect involving the memory factor, cue types, and emotions. Relevant effects involving the memory factor were followed up with subsidiary ANOVAs, up to the level of remembered verses forgotten pairwise comparisons. All results were considered reliable at $p < .05$, and a Bonferroni adjustment is applied when the multiple comparisons are applied. Partial eta-squares were reported in order to provide estimates of effect sizes.

6.3.11 Cue-Locked Analysis

The anticipatory phase consisted of a 3000ms time epoch. The cues remained on the screen from ~0-1000ms. The cue display followed a brief anticipatory period during which participants got themselves ready to see negative, neutral, or any one of the pictures according to the cue content. This period of sustained anticipatory response consisted of a 2000-3000ms time epoch that ended at the picture onset. The lead study (Galli et al., 2014; Galli, Wolpe, et al., 2011) found the Ps-Dm effect for the duration of the cue display only. According to the existing literature, emotional anticipation is studied during the late time window, 2000-3000s, which is reflective of a sustained anticipatory response. In the current experiment, this time window has been the focus for the analysis of the emotional anticipation (SPN) and the emotional memory component (Ps-Dm effect). However, it was also expected to find a Ps-Dm effect during the ~0-1000ms time window, according to the finding of (Galli, Wolpe, et al., 2011). According to the available data on anticipatory-related activity, such as Galli et al. (2011), cue-related effects start to emerge ~400ms.

An initial attempt has been made to relate emotion effects to the Contingent Negative Variation (CNV) and Stimulus Preceding Negativity (SPN) and possibly to the memory effects. In an anticipatory cueing paradigm, a CNV (early waves) is related to the characteristics of the cues (S1) and is larger at the frontocentral sites. Whereas SPN (late waves) is more related to the characteristics of S2 and is an index of emotional anticipation (Wlater et al., 1964).

The 400-1000ms time window focused on CNV-related brain activity and 2800-3000ms for SPN related emotional anticipatory activity. To capture CNV-related activity, we targeted main effects and interactions for cues and valence without memory effects. To capture SPN, cue into valence interaction was considered.

6.3.12 Picture - Locked Analysis

There were two purposes of picture-locked analysis. The first was to investigate the influence of anticipation on the early ERP components at the post-stimulus phase, and the second was to find a classical Dm effect for picture-related electrical activity.

6.4 Results

6.4.1 Behavioural Data Analysis

Procedure of statistical analysis of behavioural data is identical to the behavioural analysis given in chapter 4 section 4.3.1 (page 87).

6.4.1.1 Recognition data: Hit-rates, R-hits, K-corr-hits and False Alarm

The purpose of this analysis is to examine the recognition memory data before applying discrimination index for accuracy. A 2 (Cue: Informative, Non-Informative) × 2 (Valence: Negative, Neutral) repeated measures ANOVA was conducted for HR, R-hits, FA and K-corrected separately. ANOVA for HR revealed a significant main effect of Valence F (1, 28) = 6.19, p = .01, $\eta 2p$ = .181, that is negative pictures were recognized more than neutral pictures (M_{HR}= .72, .68; *SEs* = .017, .020). The main effect of Cue condition and Cue × Valence interaction was non-significant, (*F's* < 1.64, *P's* > .211). A separate ANOVA for R-hits also revealed a significant main effect of Valence, F (1, 28) = 21.39, p = .001, $\eta 2p$ = .433 showing that negative pictures were remembered more than neutral pictures (M_{HR}= .40, .30 ; *SEs* = .024, .017, respectively). There was no significant Cue × Valence interaction or main effect of Cue, (*F's* < 3.83, *P's* > .06). ANOVA conducted on K-corrected all revealed non-significant main effects for Cue, Valence and also a nonsignificant interaction for Cue × Valence ($F < 1$). A repeated measure ANOVA on false alarm (FA) also revealed non-significant main effects for Cue, Valence and also a nonsignificant interaction for Cue ×

Valence (*F < 1*). Table 6.1 summarizes the results for Hit rates, R-hits, K-hits and false alarms (FA).

Table 6.2: Proportions of "Old" responses on the recognition memory test as a function of Cue condition, Picture Valence and memory performance

		Negative		Neutral	
Cues	Picture status	*M*	*SD*	*M*	*SD*
Informative	Hit-rates	.72	.10	.69	.11
	R-hits	.40	.14	.30	.11
	K-hits	.32	.10	.39	.12
	FA	.18	.09	.17	.12
Non-Informative	Hit-rates	.73	.09	.68	.11
	R-hits	.39	.12	.31	.09
	K-hits	.34	.10	.37	.10
	FA	.18	.11	.20	.14

Note: Proportion of Hit rates is the sum of the proportions of "Remember (R-hits)" and "Know" (K-hits) responses. The data, "K-hits" corresponds to the uncorrected know responses. The data for the corrected know responses Kcor = K/(1-R) is given in the text. False alarm rate is proportions of old responses to new pictures.

6.4.1.2 Pr index: Recognition memory accuracy for HR, R-hits and K-corr

The Pr score for overall recognition memory score (HR) items was significantly higher for negative compared to neutral items (*M* = .55,.50; *SE* = .020, .024, respectively), F (1, 28) = 5.45, p = .027, $\eta 2p$ = .163. The main effect of Cue and the Cue × Valence interaction was non-significant, (*F's* < 2.80, *P's* > .10). The *Pr* score for R-hits was also significantly higher for negative compared to neutral items *M* = .21 .11, *SE* = .026, .028 respectively, F (1, 28) = 14.29, p = .001, $\eta 2p$ = .338. The main effect of Cue and the Cue × Valence interaction was non-significant, (*F's* < .76, P's > .38). The Pr score for corrected K items was not affected by Valence or Cue or by the interaction between Cue and Valence (*F < 1*). Overall, these results indicate that emotion enhances recognition when items are accompanied by a feeling of remembering (R) but not familiarity (K). Figure 6.2 illustrates these results.

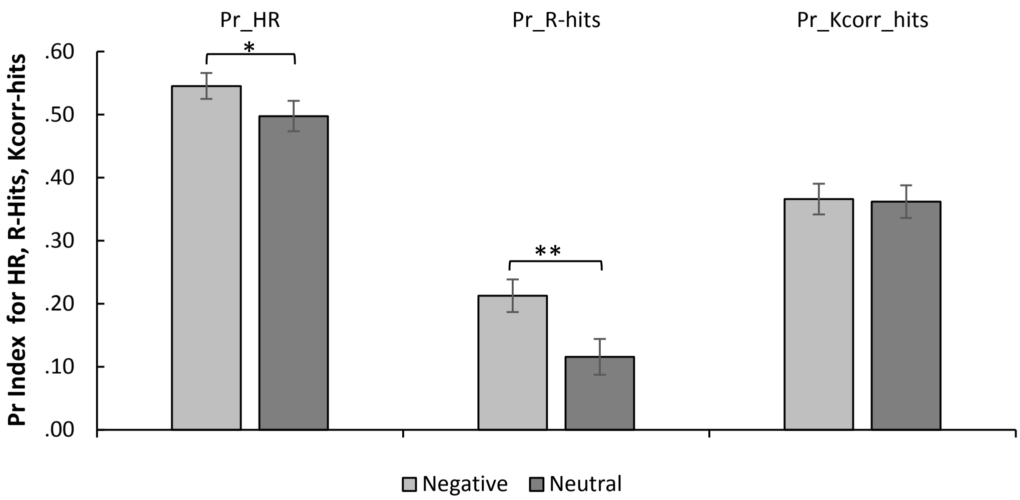


Figure 6.2: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of Valence.

Memory performance was measured with Pr, the difference between Hit-rates, R-hits, K-corr-hits and false alarm. Pr varies from 0 -1 (no discrimination between studied and unstudied pictures to perfect discrimination). Error bars show the standard error of the mean.

Recognition memory data was split by cue condition also to find the differences in the memory accuracy between valence categories. Simple main effects analysis of Pr index of Hit-rates (HR) revealed a significant main effect of the Non-Informative cue condition, F (1, 28) = 9.78, p = .004, $\eta 2p$ = .26. Overall mean scores on Pr-Index were higher for negative ($M_{Info\text{-}neg}$= .55, SEs = .022) as compared to neutral pictures ($M_{Info\text{-}neu}$= .48, SEs = .025). In contrast, a non-significant main effect was obtained for Informative cue condition, F (1, 28) = .755, p = .392, $\eta 2p$ = .026, ($M_{Info\text{-}neg}$= .54, SEs = .025; $M_{Info\text{-}neu}$= .52, SEs = .026).

Simple main effects analysis of Pr index of 'remembered' responses (R-Hits) revealed a significant main effect of the Informative cue condition, F (1, 28) = 7.56, p = .009, $\eta 2p$ = .219. Overall mean scores on Pr-Index were higher for negative ($M_{Info\text{-}neg}$= .22, SEs = .03) as compared to neutral pictures ($M_{Info\text{-}neu}$= .13, SEs = .03). A highly significant main effect was also obtained for Non-Informative cue condition, F (1, 28) = 14.40, p = .001, $\eta 2p$ = .34, ($M_{Info\text{-}neg}$= .20, SEs = .029; $M_{Info\text{-}neu}$= .10, SEs = .03).

Pr index of corrected 'Know' responses (K-corr-hits) was also put to the simple main effect analysis. Main effects of the Informative F (1, 28) = .976, p = .332, $\eta 2p$ = .034 ($M_{Info\text{-}neg}$= .36, SEs = .02; $M_{Info\text{-}neu}$= .38, SEs = .03) as well as Non-Informative cue condition were non-significant (1, 28) = 2.38, *p* = .134, $\eta 2p$ = .078, $M_{Info\text{-}neg}$= .38, *SEs* = .026; $M_{Info\text{-}neu}$= .34, *SEs* = .027 (see figure 6.3)

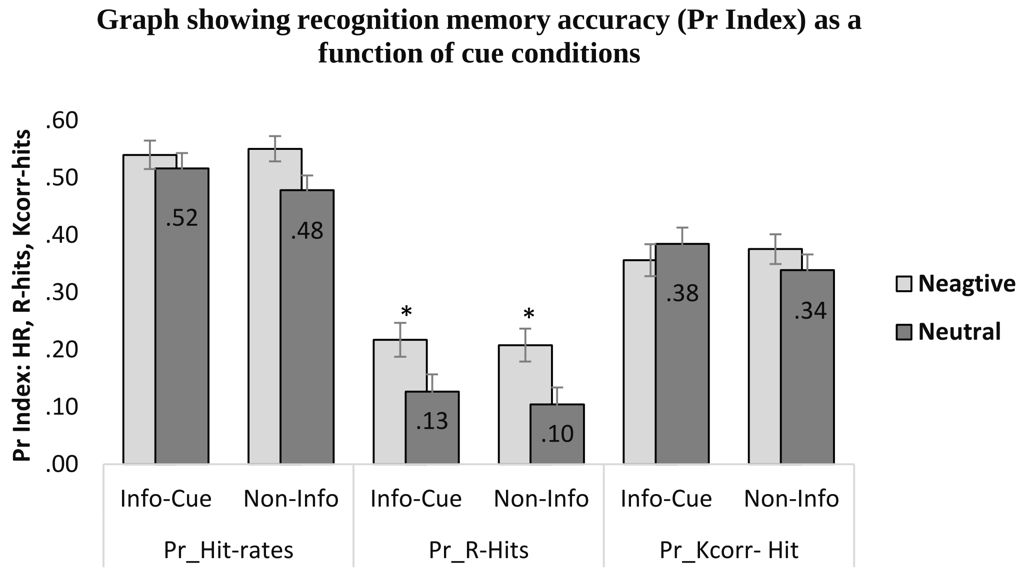


Figure 6.3: Recognition memory (Hit-rates, R-hits and K-corr-hits) as a function of cue conditions.

Memory performance data for cue condition revealed significant difference between negative and neutral item only for R-hits under both cue conditions. Error bars show the standard error of the mean.

6.4.1.3 Valence rating under anticipation process

Uncertainty about an upcoming event often creates an arousal state or an emotional context (Sarinopoulos et al., 2010a). It was hypothesized that during non-informative cue condition participants would rate negative pictures even more negative due to the uncertainty of the valence of the picture. To rule this factor out, participants' SAM ratings (only negative high and low arousal) were analysed with ANOVA. A significant main effect for the Cue condition, F (1, 28) = 4.95, *p* = .034, η2p = .150, indicated that participants rated negative pictures as more negative under both cue condition as contrary to the hypothesis. The mean scores on valence rating were as high for Info-Cue (M = 1.70, SE = .042) as under Non-Informative cue condition (M = 1.75, SE = .044).

6.4.1.4 Reaction time Analysis

A 2 × 2 ANOVA with Cue × Reaction Times revealed no significant main effect for Cue *F* (1, 28) = .881, *p* = .356, η2p = .031; Valence *F* (1, 28) = .533, *p* = .590, η2p = .019 and no interaction between the two, *F* (1, 28) = 1.08, *p* = .346, $\eta^2 p$ = .037.

6.4.2 Cue-Locked ERP Analysis

6.4.2.1 Cue display: Early time window (400-1000ms)

Mean amplitudes from the 3 time windows (400-600 ms; 600-800 ms; 800-1000 ms) were extracted. Repeated measures ANOVA with factors Time × Cue × Valence × Memory × Anteriority × Laterality gave rise to a significant interaction between Time × Cue × Valence × Memory, F (1, 28) = 2.97, p = .059, η2p = .096. Subsidiary analysis revealed that Cue × Valence × Memory, F (1, 28) = 8.52, p = .007, η2p = .233 and Cue × Valence × Memory × Laterality, F (1, 28) = 4.185, p = .020, η2p = .130 interaction was significant for the 600-800ms time window, but not for the 400-600 ms and 800-1000 ms (F < 1) window. To better understand this interaction, Valence × Memory × Laterality, ANOVAs were computed for Info-Cue and Non-Info cues separately. For the Non-Info cues condition, the interaction was significant for Valence × Memory × Laterality, F (1, 28) = 3.13, p = .051, η2p = .101, but not for the Info-Cue condition, F (1, 28) = 1.29, p = .281, η2p = .044. ANOVA split by Valence categories revealed a significant main effect of memory, significant only for neutral stimuli, F (1, 28) = 4.46, p = .044, η2p = .137 but not for negative stimuli F (1, 28) = .992, p = .328, η2p = .034. The significant main effect of memory for neutral stimuli, showing that the amplitude for the remembered items was a more negative-going deflection (M = -6.68, SE = 4.96) than for forgotten items (M = 8.60, SE = 3.56) over the midline anterior site F (1, 28) = 6.26, p = .018, η2p = .183 than right or left site (F < 1). The interaction between Time × Cue × Valence × Memory × Anteriority × Laterality did not reach significance, F (2, 56) = 1.46, p = .216, η2p = .050.


a)
Left
Midline
Right
Negative
Neutral
Cue display
Sustained anticipation
SPN
Amplitude (µV)
Time (ms)
Remembered
Forgotten


b)
Left
Midline
Right
Negative
Neutral
Cue display
Sustained anticipation
SPN
Amplitude (µV)
Time (ms)
Remembered
Forgotten

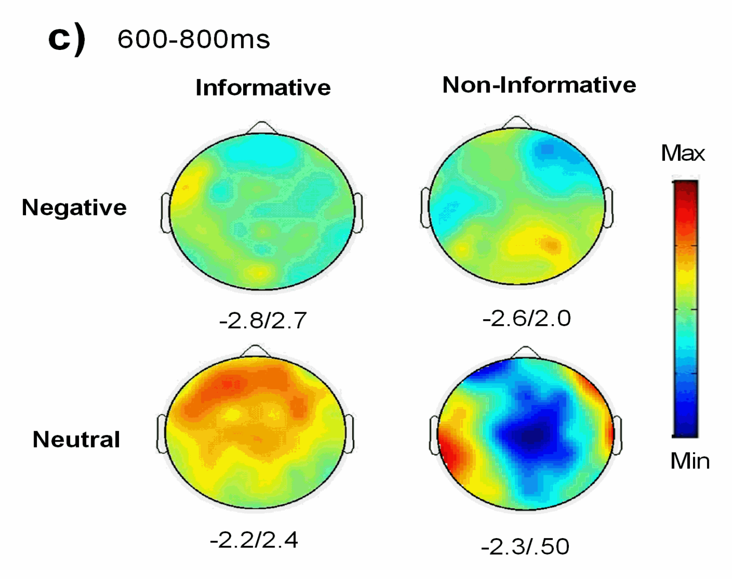


Figure 6.4: ERP waveform and Scalp maps representing cue related encoding activity across picture valence 600-800ms time bin.

a) ERP waveform plotted on left, midline and right electrodes for the Info-Cue-related activity according to subsequent memory (Remembered vs. Forgotten items) and valence (Negative vs. neutral). Amplitude in microvolts is on the y-axis and time in milliseconds is on the x-axis.

b) ERP waveform plotted on left, midline and right electrodes for Non-Info-Cue related activity according to subsequent memory (Remembered vs. Forgotten items) and valence (Negative vs. neutral). Amplitude in microvolts is on the y-axis and time in milliseconds is on x-axis.

c) Scalp maps plotting 'remembered' minus 'forgotten' mean ERP amplitude scores for 600-800ms.

6.4.2.2 1000-3000 ms: Dm effect during sustained anticipatory activity

This time window was examined for the Ps-Dm effect related to the electrical activity after the cue display. Repeated measures ANOVA revealed a significant interaction for Cue × Valence × Memory × Anteriority × Laterality, F (1, 28) = 3.78, p = .029, η2p = .119. To understand this interaction an ANOVA was computed separately for Info-Cue and Non-Info cues. For Info-cues, the Valence × Memory × Anteriority × Laterality F (1, 28) = 4.02, p = .023, η^2p = .126 interaction was significant, but not for Non-Info cue condition F (1, 28) = 1.37, p = .262, η2p = .047. Subsidiary analysis revealed a significant Memory × Anteriority × Laterality F (1, 28) = 7.44, p = .001, η2p = .210 for neutral items but not for negative ones, F (1, 28) = .145, p =.865, η2p = .005. The Memory × Anteriority interaction was significant F (1, 28) = 4.30, p =.047, η2p = .133, However, a simple effect analysis revealed that the memory effect was not significant at any of the scalp Anteriority, anterior F (1, 28) = 3.85, p = .54, η2p = .014 and posterior F (1, 28) = .516, p =.478, η2p = .018 nor the laterality, F (1, 28) = .901, p =.412, η2p = .031.

6.4.2.3 2800-3000ms: Stimulus-Preceding Negativity (SPN)

An examination of the SPN (emotional anticipation) into 2800-3000ms time windows yielded non-significant results, *F* (1, 28) = .003, *p* = .955, η^2_p = .000.

6.4.2.4 CNV (400-1000ms)

A Cue × Valence × Memory × Anteriority × Laterality ANOVA revealed a robust main effect of the Cue condition, *F* (1, 28) = 7.97, *p* = .009, η2p = .222 with the Info-Cue eliciting a more positive going waveform (M = 2.64, SE = 1.51) than Non-Info cue condition (M = -.451, SE = 1.24). Subsidiary analysis of Cue × Valence *F* (1, 28) = 8.77, *p* = .006, η2p = .239 was conducted. The main effect for Valence *F* (1, 28) = 5.47, *p* = .027, η2p = .164 was significant for Info-Cue but not for Non-Info cue, *F* (1, 28) = .106, *p* = .748, η2p = .004. Negative stimuli showed greater positivity (M = 5.04, SE = 2.07) than neutral stimuli (M = .234, SE = 1.54). Another significant interaction involves Cue × Memory× Anteriority *F* (1, 28) = 4.48, *p* = .043, η2p = .138. Subsidiary analysis revealed that Memory× Anteriority *F* (1, 28) = 4.28, *p* = .048, η2p = .133, interaction was significant for the Info-Cue but not for the Non-Info cue, Memory× Anteriority *F* (1, 28) = 1.68, *p* = .204, η2p = .057. However, the memory effect was not significant at any of the A-P Anteriority (F <1, P > .05). Cue × Valence × Memory *F* (1, 28) = 2.46, *p* = .128, η2p = .081 and Cue × Memory *F* (1, 28) = .014, *p* = .906, η2p = .001 did not reach significance.

Taken together, the cue-locked analysis to cues and sustained anticipatory activity revealed a Ps-Dm effect for neutral cues only. The significant Ps-Dm effect for Non-Info cue conditions was elicited in the earlier time window (600-800ms) while for informative, neutral cues were elicited during the late time windows.

6.4.3 Picture-Locked ERP analysis

6.4.3.1 200-300 ms (Negative peak N2)

A main effect of cue type was observed at O1, *F* (1, 28) = 4.184, *p* = .050, η2p = .130. Mean amplitude for Info-Cues was more positive (M = 10.03, SE = .984) than for Non-Info Cues (M= 9.59, SE = .950). A significant main effect of Valence *F* (1, 28) = 19.27, *p* = .001, η2p = .408 indicated larger positivity for negative (M = 10.26, SE =.986) than for neutral (M = 9.36, SE =.948) stimuli. Memory *F* (1, 28) = 19.27, *p* = .001, η2p = .408 was also significant with forgotten being more positive (M = 10.09, SE =.991) than remembered (M = 9.53, SE =.991). The rest of the interactions in this time window were all non-significant (F <1, P < .05)

6.4.3.2 400-1000ms (Dm effect)

The picture-related effects were quantified by measuring mean amplitude values in the 400-1000ms time window. A repeated measures ANOVA revealed a robust main effect of

Memory, $F(1, 28) = 12.74$, $p = .001$, $\eta^2_p = .313$, indicating an overall larger positivity for the subsequently remembered (M = 25.29, SE = 3.59) pictures over the forgotten pictures (M = 19.83, SE = 3.14). The main effect of Valence was also significant $F(1,28) = 136.91$, $p = .001$, $\eta^2_p = .830$, indicating larger positivity for the negative items (M = 34.05, SE = 3.88) compared to neutral (M = 11.07, SE = 2.91).

A significant interaction for Valence × Memory × Laterality $F(2, 56) = 6.07$, $p = .004$, η2p = .178, was further elucidated for negative and neutral pictures. A Memory × Laterality interaction was significant for negative $F(2, 56) = 14.65$, $p = .001$, η2p = .344, as well as for neutral pictures $F(2, 56) = 13.13$, $p = .001$, η2p = .319. The main effect of Memory was found to be significant for negative pictures at left $F(2, 56) = 6.13$, $p = .020$, η2p = .180, and midline sites $F(2, 56) = 15.35$, $p = .001$, η2p = .354, and for neutral as well at the left $F(2, 56) = 11.90$, $p = .002$, η2p = .298, and the midline scalp sites $F(2, 56) = 13.56$, $p = .001$, η2p = .326. The interaction was driven by a difference between negative and neutral on the right side $F(2, 56) = 6.37$, $p = .018$, η2p = .185, as the mean amplitude of the remembered negative pictures was greater (M = 129.91, SE = 14.79) than the forgotten (M = 112.21, SE = 13.25). However, this effect was not significant for the neutral pictures at the right scalp site $F(2, 56) = .971$, $p = .337$, η2p = .034 (see figure 6.4-a)

The Cue × Valence × Anteriority × Laterality interaction was significant $F(2, 56) = 4.32$, $p = .018$, η2p = .134. For Non-Info cue, Valence × Anteriority × Laterality interaction was significant $F(2, 56) = 9.31$, $p = .001$, η2p = .251, but not for the Info-Cue $F(2, 56) = .265$, $p = .768$, η2p = .009. Further subsidiary analysis revealed that Anteriority × Laterality interaction was significant for negative pictures $F(2, 56) = 3.19$, $p = .049$, η2p = .102 where amplitude for negative pictures was more pronounced at both the left, midline anterior, and posterior scalp site than on the right site. This interaction was non-significant for neutral pictures $F(2, 56) = 1.71$, $p = .189$, η2p = .058 (see figure 6.4-bScalp map).

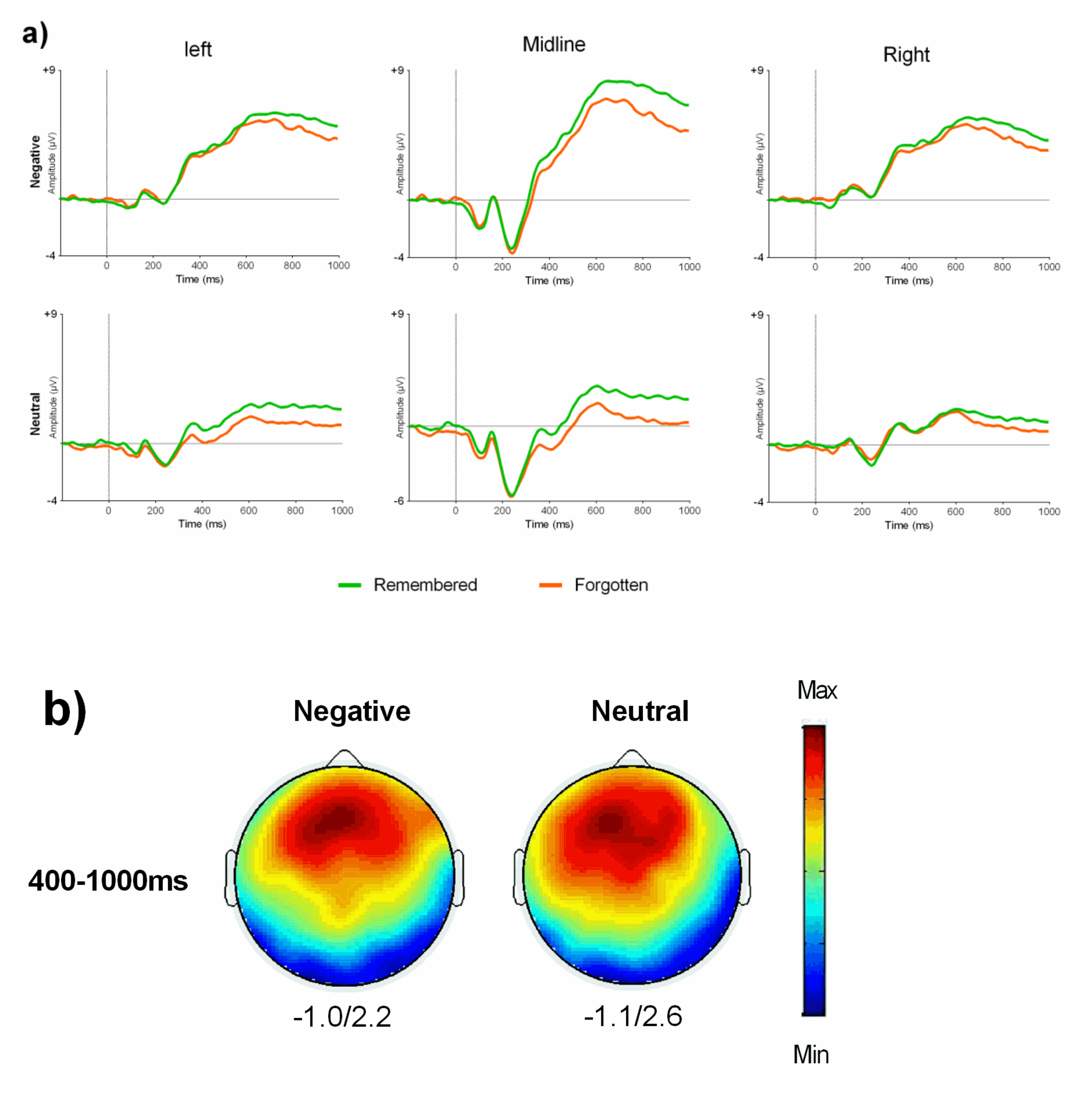


Figure 6.5: ERP waveform and Scalp maps representing picture related encoding activity for 400-1000ms time bin.

(a) ERP waveform plotted on left, midline and right electrodes for post-stimulus picture-related activity according to subsequent memory (Remembered vs. Forgotten items) and valence (Negative vs. neutral). Amplitude in microvolts is on the y-axis and time in milliseconds is on x-axis.

b) Scalp maps plotting 'remembered' minus ' forgotten' mean ERP amplitude scores for 400-1000ms.

6.5 Discussion

In this experiment, the main focus was to examine the subsequent memory effect at the anticipatory phase when the cues provide full or partial information about the valence of the imminent pictures. The findings revealed a subsequent memory effect for informative as well as for non-informative cues, but not for emotional rather than neutral cues. It was thought that anticipation of something aversive would involve greater brain activation and hence, preparation to deal with the situation, which might influence memory. However, these findings gave new insight into anticipatory processes; that is, anticipation does not necessarily orient attention towards negative information. Rather, it might engage the voluntary process of attentional disengagement from the negative information. The findings of the current experiment provide evidence for this phenomenon. During the anticipatory phase, analysis of instant responses to cues revealed avoidance from the negative cues when the cue informed participants that the valence of the picture was negative. The avoidance response was even elicited for the Non-Informative cues, as the memory was enhanced by cues pertaining to neutral pictures only. For informative cues, a preference for attending to neutral over emotional cues was observed during the sustained anticipatory phase. In this phase, brain potentials related to remembered neutral information were larger than the emotional ones.

Disengagement from negative information is an important attribute of normal human brain functioning. In contrast, greater difficulty in disengagement from negative emotional information is linked to rumination and anxiety (Fox, Russo, & Dutton, 2002). To explain the reason for the difficulty in disengagement, models of coping style posit that individuals high in anxiety have a low tolerance for negative arousal (Egloff & Hock, 1997). Since all the participants in the current experiment were in the normal range of scores on the Depression, Anxiety and Stress Scale (DASS), it seemed quite easy for them to avoid negative information and to focus on the neutral stimuli only. However, one cognitive factor which has been closely correlated with attentional disengagement is the belief about the emotion (Dennis & Halberstadt, 2013). For example, the belief that negative emotions are undesirable might cause one to direct selective attention away from the negative stimuli and towards positive stimuli (Dunsmore, Her, Halberstadt, & Perez-Rivera, 2009). However, an investigation of participants' beliefs about the emotional information was beyond the scope of the current study.

The avoidant coping mechanism hypothesis was tested by Dennis and Halberstadt (2013) in a series of two studies using a dot-probe task. In the first experiment, beliefs that negative emotions are dangerous were measured using nine items selected from Parent's Belief About Children's Emotion questionnaires (Dunsmore et al., 2009). Participants' beliefs were correlated with a preference for positive facial cues over negative facial cues. In the second experiment of the series, which was on exposure to negative cues, early attentional disengagement was observed between 500 to 750 ms. Following that, a subsequent orientation towards positive cues started between 750-1000 ms (Dennis & Halberstadt, 2013). A similar trend has been observed in the present experiment. During the exposure to the cue, no preference for the negative cue was elicited in the earlier time window (0-1000ms); however, a Dm effect for the neutral cues was observed in the late time window (1000-3000ms). This pattern of results suggested that participants used an avoidant coping mechanism where they shifted their attention away from the negative upcoming stimuli and focused on neutral information only.

Anticipation is correlated with attention, and some studies suggest that there is competition for neural resources that can bias attention in several ways (Bocker et al., 2001). The P100 ERP component is a positive deflection that peaks between 80-120ms after a visual stimulus. It is thought to be larger for attended than unattended stimuli (Mangun, 1995). It is also larger in response to expected than unexpected stimuli (Bocker, Baas, Kenemans, & Verbaten, 2001). Early ERP components were investigated to understand the influence of anticipation on the attention-related ERP components at the post-stimulus phase. At post-anticipation it was expected that P1 or N1 would be modulated as a function of cue; specifically, informative negative cues. However, non-significant P1 and N1 indicated that attention was directed away from the affective stimuli. The N2 is interpreted as a visually evoked potential in response to significant stimuli (Onoda et al., 2006). Higher mean amplitudes over the O1 electrode site were found regardless of valence, for informative cues compared to Non-informative cues. These findings are consistent with a prior study (Onoda et al., 2006) which found an influence of anticipation on M120 for visual evoked magnetic fields which is the counterpart of N2 in ERP.

For the non-informative cue condition, it was predicted that valence-specific preparatory processing was not necessary to elicit the Ps-Dm effect. Findings showed a significant Ps-Dm effect for neutral pictures relative to emotionally negative pictures in the earlier time windows (600-800ms). However, these results appeared to be significant without any qualitative differences in scalp distribution, i.e., Anteriority and laterality. These findings suggest that memory is independent of preparatory processes during anticipation. Initially, it was proposed that random fluctuations are responsible for the Ps-Dm effect for the Non-Info cue condition.

These findings also suggest that when participants are unaware or uncertain of the valence of upcoming images, they allocate more attentional resources toward anticipating the unexpected stimuli, regardless of the valence of the pictures. Evidence for this came from Jin et al. (2013) who found a larger P2 amplitude, which reflected attention allocation and perceptual analysis during unpredictable trials (Jin et al., 2013; Key, Dove, & Maguire, 2005; Thorpe, Fize, & Marlot, 1996; Yuan et al., 2011). Taken together, the findings of the Info-Cue and Non-Info cue conditions suggest that preparatory processes are not necessary for eliciting a memory-related component. Findings revealed an innovative explanation for the anticipatory model; that is the avoidant coping mechanism gets activated when participants found the upcoming stimuli undesirable or uncomfortable, and, as a result, drew their attention away from the emotional stimuli and towards the less arousing neutral stimuli.

In the electrophysiological literature, the Contingent Negative Variation (CNV) and the Stimulus Preceding Negativity (SPN) are frequently discussed with respect to anticipation (Boxtel et al., 2004). The CNV is described as early waves associated with cue characteristics, where the SPN is described as late waves associated with the expectancy of emotional stimuli. Based on the definition of CNV and SPN, cue epochs were investigated for two-time windows: early (CNV: 400-1000ms) and late (SPN: 1000-3000ms). We expected more significant cue-related interactions during 400-1000ms time window, and more picture-valence and memory-related interactions during 1000-3000ms time window. However, the statistical analysis of these time windows showed significant main effects for the Non-info cue condition during 400-1000ms time window and for the anticipation of neutral pictures during 1000-3000ms time window contrary to the study predictions.
A classical Dm effect was observed at the post-stimulus phase, where negative remembered pictures were shown to evoke more positive-going waveforms than the neutral remembered pictures, regardless of cue condition. These effects were found to be more pronounced over right and midline scalp sites. Subsequent memory effects are usually obtained with frontal-central or centroparietal recording sites; however, in the current study, we found significant results without any preference for location. The post-stimulus findings are different from pre-stimulus findings, as the ERP related to the memory of the neutral picture was dominant. The difference in findings suggests that pre- and post-stimulus phases are dissociable from each other. This explanation corroborates the reasoning provided in the Galli et al. (2011) study. Initially, it was argued that anticipatory processes reflect post-anticipatory processes, because if it prepares participants for encoding then it should reflect encoding at the post-anticipatory phase too. However, the leading study provides no evidence to support this (Galli et al., 2011).

Another consistent finding from the previous two studies and in the current study is the non-significant behavioural outcome of anticipation. These findings suggest two possibilities: first, anticipation is not associated with behavioural memory advantages, or; second, anticipatory processes are dissociable at all levels of anticipation, such as pre-, post- and behavioural levels. Moreover, the studies on the effects of anticipation on emotional memory (Galli et al., 2011; Padovani et al., 2011) have not reported behavioural findings, which also supports this conclusion.

Cues may improve cognitive processing of ensuing stimuli, and RT provides an index of efficient and effective processing. Reaction time analysis was conducted across cues types and valence categories to test the possibility that foreknowledge of the valence of stimuli enhances the processing efficiency for those trials. Results revealed no significant preferences for Info-Cue over Non-Info-Cue cues in terms of RTs. Notably, a close examination of RTs related to descriptive data revealed that overall, participants' RT for Non-Info cue trails were faster than for the Info-Cue trials. These results are consistent with the (Jin et al. 2013) finding, where demonstrated faster reaction times for unpredictable trials compared to predictable ones.

Additionally, there were faster RTs for negative pictures compared to neutral pictures (statistically non-significant) regardless of the cue conditions. However, negative pictures were rated faster in non-informative trials than negative pictures were in informative trials. These results might be explained in terms of the 'cognitive control model' of switch costs. According to this model, informatively cued trials result in longer reaction times because of the failure of the full engagement of anticipatory processes in those trials (Kieffaber & Hetrick, 2005). Further support for these explanations occurred when we found a non-significant subsequent memory effect for emotional cues in informed trials. The cognitive control hypothesis also agrees well with the account provided by Castelfranchi and Miceli (2011) for the relationship between emotion and anticipation. According to the explanation provided, emotion mediates anticipatory activity when the anticipatory cue meant some real threat related to the upcoming event or when a belief is already formed due to a past experience about the emotionally negative event.

Subjects' valence ratings of the to-be-anticipated stimuli might account for the significant Ps-Dm effects for neutral cues compared to emotionally negative ones. Participants were required to rate the valence of each picture using SAM on a five-point scale. The greater variability was found in SAM ratings for negative pictures as compared to neutral pictures. Hence, an equal number of high and low arousal pictures were selected, and greater variability was found for low arousal pictures. For neutral pictures, there appeared to be a cue-picture match while for emotionally negative pictures, evaluation regarding valence was not consistent, which might have accounted for these results. It appeared that although the cues informed participants that they are going to see the emotionally negative picture but they saw low arousal negative pictures, they did not evaluate them as too intense in emotionality dimension. This factor created a sort of inconsistency in the evaluation of emotional pictures which affected anticipation of emotionally negative pictures also. In contrast, the information which cue provided about the neutral pictures were more consistent and hence its evaluation and anticipation by the participants. It all resulted in a memory difference for neutral pictures but not for emotional ones.

Cue-picture consistency for the negative pictures might be achieved by the selection of highly arousing pictures, which might ensure that participants perceive the ensuing pictures as aversive or posing a real threat One line of evidence for this possibility was discussed by Böcker, Baas, Kenemans, & Verbaten (2001), who suggested larger SPN-related negativity for threat cues as compared to safe cues. This might be done for future experiments, as it is notable that in all the cueing paradigm fMRI studies in which findings showed similar brain activity in pre- and post-stimulus phases, only high arousal pictures were selected (Herwig, Abler, Walter, & Erk, 2007; Mackiewicz et al., 2006b; Nitschke, Sarinopoulos, MacKiewicz, Schaefer, & Davidson, 2006; Simmons, Matthews, Stein, & Paulus, 2004). In this way, we may enhance the capacity of our anticipatory activity so that it is more active or attentional engaging.

An overview of non-significant descriptive statistics revealed that RT for Non-Info cue trials was faster than Info-Cue cue trials. These results are consistent with the (Jin, et al. 2013) finding that faster reaction times for unpredictable trials were faster than predictable ones. Additionally, there were faster RTs for negative pictures than for neutral pictures (statistically non-significant) regardless of the cue conditions. However, negative pictures were rated faster in non-informative trials than negative pictures in informative trials.

6.6 Conclusion

Thus far, the findings of the current experiment are consistent with an avoidance coping mechanism during the anticipation phase. Findings revealed evidence that the memory-related ERP associated with neutral content was more pronounced than it was for emotional content. From an evolutionary standpoint, avoiding aversive events is advantageous for survival and reproduction. The findings of the current study also showed that anticipation is not a passive process. Through selective attention, individuals decide where to place their cognitive resources, which determines what information in the environment will receive more in-depth processing and what information will be relatively ignored (Deutsch & Deutsch, 1963). Vigilance (when attention is drawn towards a stimulus) and avoidance (when attention is directed away from a stimulus) are two mechanisms that may account for selective attention. According to the functional definition of emotion, emotions convey information relevant to one's goals, thereby motivating prioritized processing of emotional information (Ellsworth & Scherer, 2003). Contrary to this, findings showed disengagement of attention from the aversive upcoming content. This raises the question as to what factors draw participant's attention towards emotional stimuli.

6.7 Future Direction

The findings of chapter 5 and chapter 6 were similar in the respect that both studies did reveal a memory difference but not specific to the anticipation of emotionally negative pictures. These findings highlight the possibility that Ps-Dm effect may be more an arousal-based phenomenon than valence based. In the next experiment, only high-arousal negative pictures will be used with the same experimental setup used in this study. Knowing that an upcoming stimulus is high in emotional intensity may lead to vigilance and thereby bias attention towards negative stimuli. The idea is that high-arousal emotional information would be processed automatically, creating subsequent effects. It would be interesting to examine, whether processing of high-arousal information is dependent more on vigilance or on avoidance mechanism (Posner & Petersen, 1990). A number of studies have found significant Ps-Dm effects for high-arousal negative pictures (Mackiewicz et al., 2006b; Nitschke et al., 2009; Sarinopoulos et al., 2010a). These studies demonstrated that it is not valence, but rather an arousal level of the emotional stimuli, that promotes enhanced memory for emotional stimuli (Cahill & McGaugh, 1996; Dolcos, LaBar, & Cabeza, 2004; Hamann et al., 1996; Hamann, 2001).

Chapter 7: Anticipation of high arousal emotional stimuli under informative and non-informative cues

7.1 Overview

The previous study reported in chapter 6 found a significant difference between remembered and forgotten waveform Ps-Dm effect for neutral pictures at the anticipatory phase for Informative and Non-informative cue conditions. The findings were attributed to the use of low arousal emotional pictures in that experiment which resulted in a non-significant memory for a negative picture. To test if the arousal of the emotionally negative pictures is responsible for Ps-Dm effect, in the current study, only high-arousal negative pictures were presented under both cue conditions. Findings revealed a Ps-Dm effect regardless of cue condition during 400-600ms time window. These findings mirror the behavioural findings reported in chapter 4 and suggested that the presence of the cues is important than its informative content. The Ps-Dm effect was not found for emotionally negative stimuli in the time window from 1000-3000ms which signify that Ps-Dm effect is more related to the bottom-up processing of the stimuli as it was seen only for the time duration when the cue was present on the screen and diminished when the cue disappeared. These results also suggest that the anticipation is not a unitary process, rather it has distinct temporal stages which are supported by the dissociable neural mechanism.

7.2 Introduction

Memory for highly arousing emotional events is stronger than memory for neutral events (LaBar & Cabeza, 2006). Emotional events are not only remembered with greater detail (Dolcos et al., 2004; Alexandre Schaefer & Philippot, 2005) but also recalled with enhanced accuracy (LaBar & Cabeza, 2006). This phenomenon is referred to as emotion-enhanced memory (EEM; Talmi, Schimmack, Paterson, & Moscovitch, 2007). In event-related potential (ERP), literature an index of EEM is called the subsequent memory effect or the difference due to memory effect (Dm effect). The Dm effect is the difference between the amplitude of remembered and forgotten trials. Previous studies have found that remembered trials have a more positive-going deflection than do forgotten trials (Paller & Wagner, 2002). This reflects the fact that emotional arousal influences attention and perception when individuals are exposed to the high-arousal emotionally negative or positive pictures (Greenberg, Carlson, Rubin, Cha, & Mujica-Parodi, 2015)

A number of studies have demonstrated that memory is influenced by emotional arousal via amygdala activation and the adrenergic system (Sharot & Phelps, 2004; Cahill & McGaugh, 1998. Neuroimaging studies have reported an association between amygdala activation during encoding, retrieval, and long-term memory formation (Cahill, et al., 1996). Recently, investigations have shown that these areas get activated even before the presentation of arousing stimuli, merely in response to the anticipation of emotionally arousing stimuli (Cahill & McGaugh, 1998b; Ledoux, 2002; Mackiewicz et al., 2006b; Nitschke et al., 2006). This phenomenon has been termed the 'pre-stimulus subsequent memory/Dm effect'(Ps-Dm effect) in two ERP studies (Galli et al., 2014; Galli, Wolpe, et al., 2011) and in multiple fMRI studies (Gole, Schäfer, & Schienle, 2012; Mackiewicz et al., 2006b; Nitschke et al., 2006; Sarinopoulos et al., 2010b). It is called the Ps-Dm effect because the contrast between the neural activity of remembered and forgotten items was found before the occurrence of the emotionally negative event. In ERP studies, this phenomenon has been explained in terms of a cognitive factor, i.e., the preparation that facilitates encoding of emotionally negative stimuli (Galli, Choy, & Otten, 2012). However, in fMRI studies the Ps-Dm effect has been attributed to the emotional arousal of the to-be-anticipated emotional pictures (Mackiewicz et al., 2006b). The studies reported in chapter 4 and 6 of this project, initial evidence suggests that the Ps-Dm effect is independent of preparatory processes. In the current experiment, the role of emotional arousal on the pre-stimulus subsequent memory (Ps-Dm effect) anticipation phase has been examined in informative and non-informative cue conditions.

7.2.1 Emotional memory and arousal

The arousal level of the emotionally negative stimuli is a critical factor that contributes to emotional memory enhancement at the encoding (Cahill, Babinsky, Markowitsch, & McGaugh, 1995). Greater activation in the amygdala and hippocampus was not only observed after exposure to emotionally arousing stimuli at the encoding phase (Cahill, Babinsky, Markowitsch, & McGaugh, 1995; McGaugh, 2000; Murty, Ritchey, Adcock, & LaBar, 2010; Richardson, Strange, & Dolan, 2004) but also during recollection of emotional material (Cahill et al., 1996; Kensinger & Schacter, 2006; Murty et al., 2010).

7.2.2 Arousal and attention

One factor that contributes to the enhancement of emotional memory is the allocation of attentional resources towards stimuli. Emotional stimuli are processed preferentially because they draw attentional resources (Lang et al., 1998) at the cost of peripheral details. This is called a 'memory narrowing effect' (Burke, Heuer, & Reisberg, 1992; Reisberg & Heuer, 1992) or a 'memory trade-off effect' (Kensinger, Garoff-Eaton, & Schacter, 2007). Studies report that more arousing stimuli enhance memory for the gist, i.e., a type of memory which lacks details (Adolphs, Tranel, & Buchanan, 2005). Another line of evidence showed that emotional arousal enhances memory for the perceptual details of an item

(Kensinger, 2004; Kensinger, 2009a, 2009b; Kensinger et al., 2007; Maratos, Mogg, & Bradley, 2008; Mara Mather & Nesmith, 2008). Arousal-biased Competition (ABC) theory (Mather & Sutherland, 2011) explains the mechanism behind this trade-off. According to this account, arousal level intensifies the biased competition processes that make mental representations of emotional stimuli more salient than other competing representations, such as neutral stimuli. There are a number of studies which have tested propositions made by the ABC framework in the context of post-stimulus memory effects; however, it is unknown if this account is generalizable across pre-stimulus phase too.

Explanations involving the effects of arousal on the emotional processing of stimuli produce more predictable findings compared to valence-based explanations. Arousal elicits a positive-going waveform from about 200ms until stimulus offset. This effect varies with task relevance within the P300 range (Olofsson, Nordin, Sequeira, & Polich, 2008). Arousal-related ERP modulation has been linked with automatic attention at middle-range latencies while stimuli that are intrinsically motivating facilitate processing for subsequent memory storage at longer latencies (Olofsson et al., 2008). ERP arousal effects can be inhibited by emotional re-appraisal and task instructions, especially at longer latencies.

7.2.3 Modulation hypothesis

7.2.3.1 Consolidation

Longer retention intervals or consolidation is considered a crucial factor in arousal-based memory traces (Sharot, Verfaellie, & Yonelinas, 2007; Sharot et al., 2008). In recognition memory tasks, the effects of relatively short retention intervals tend to be robust and stable if long study-test intervals are used (Payne & Kensinger, 2010; Sharot et al., 2008) These delayed effects of emotional content on recognition memory are likely due to the long time course of action of emotion-related hormones and transmitters McGaugh, 2004) However, enhanced memory for emotional stimuli has also been observed immediately after encoding, which cannot be readily explained by more efficient consolidation (Schwarze, Bingel, & Sommer, 2012).

Emotional anticipation

Emotional anticipation is an essential regulating factor of human behavior. It enables the anticipation of positive outcomes and the avoidance of danger. It helps us to survive by allowing us to choose from alternative actions. A number of paradigms have been employed to investigate emotional anticipation, such as cueing paradigms (S1-S2), monetary reward and punishment paradigms, and picture-viewing paradigms. The most widely used paradigm has been the picture-viewing paradigm which allows manipulation of a specific emotional state during anticipation. During emotional picture processing several psychophysiological measures show variations that are differently modulated by the pleasantness or the unpleasantness of emotional content (Lang, Greenwald, Bradley, & Hamm, 1993). According to the dimensional model of emotion (Lang et al., 1993) valence and arousal dimensions describe the emotional experience. The valence dimension describes the pleasantness and unpleasantness of the emotional state and is supposed to be linked to the activation of the appetitive or defensive motivational system. Arousal is related to the intensity of the motivational activation and engagement (Bradely et al., 2001). Research into the cognitive neuroscience of emotional anticipation and its impact on memory is in its infancy. Therefore, it is still largely unknown whether it is valence or arousal that plays its role in modulating memory at the pre-stimulus phase. This is because the findings of a handful of the previous ERP (Galli et al., 2014; Galli, Wolpe, et al., 2011) and fMRI studies (Mackiewicz et al., 2006b; Mackintosh & Mathews, 2003; Nitschke et al., 2006) are inconsistent. That is, these studies do not corroborate each other's findings that emotional anticipation enhanced memory encoding. It is exactly this question that this thesis sought to answer.

7.2.3.2 Emotional anticipation and memory

That arousal level affects emotional processing and enhanced recollection at the pre-stimulus phase is a somewhat new position. One piece of evidence comes from a neuroimaging study where greater activity was observed in emotion and memory specific brain regions (the amygdala and hippocampus) during anticipation of highly arousing negative stimuli (Mackiewicz et al., 2006b).

One issue related to the anticipation that still needs to be validated is the question of whether the pre- and post-stimulus brain activations are dissociable from each other. Numerous electrophysiological studies (e.g., Galli, Wolpe, et al., 2011) and the findings of chapter 6 provided evidence for the dissociability of the pre- and post-stimulus neural activation. However, other studies have shown that pre- and post-stimulus cortical activations are analogous. These studies found similar pre-activations in brain regions such as the fusiform gyrus and left the lateral temporal region for pictures and words, respectively (Park & Rugg, 2010, 2011). Taken together, one theme emerges from these neuroimaging studies; that is, the pre- and post-stimulus cortical activations are analogous (Addante, de Chastelaine, & Rugg, 2015) and thought to be governed by a single system (Ledoux, 2002; Nitschke, Sarinopoulos, Mackiewicz, Schaefer, & Davidson, 2006; Pavlov, 1927). Since only the high-arousal negative stimuli have been selected for the current study, we expected to observe similar neural activations at pre- and post-stimulus phase.

To examine whether the Ps-Dm effect depends on the motivational significance of the upcoming stimuli, or instead the information content of the upcoming stimuli, Bollinger, Rubens, Zanto & Gazzaley (2010) manipulated level of preparedness with neutral stimuli (faces, scenes) using intentional encoding. The findings revealed that pre-stimulus expectations direct attention under the influence of knowledge about the upcoming stimuli's content, which in turn leads to the enhancement of memory performance. Moreover, the Ps-Dm effect was not just confined to emotional stimuli; the same preparatory processes worked for the neutral stimuli too. To further elaborate on the findings, they made a distinction between the type of the expectation and its relation to memory. They emphasized that the Ps-Dm effect for neutral stimuli was not dependent on the motivation or the reward value (Gruber & Otten, 2010) of the imperative stimuli, but rather purely relied on the information about the nature or content of the upcoming stimuli (Bollinger et al., 2010).

7.2.4 Rationale and Aims

The general purpose of the study is to examine emotional memory at the pre-stimulus phase when pictures (S2) are high in negative arousal. Specifically, we are interested in how the mental representation or perception of something intense in emotional arousal affects anticipation and thereby memory. Does anticipation of something intense in aversion yield different results compared to anticipation when participants are informed of the intensity of the pictures? To orient participants' attention towards the intensity of the picture, the post-experimental task involved rating the pictures on the intensity of emotional arousal. This was in contrast to previous studies (chapters 5 & 6), where participants rated the valence of the pictures.

Additionally, in the previous three studies, the focus was on the cue's (S1: Stimulus 1) properties. Two levels of the content of cues' information were manipulated. In this experiment, the focus has been shifted from the cue to the picture (S2: Stimulus 2). Variability in the arousal level of emotionally negative stimuli in Study 3 (Chapter 5) was identified as an explanation for a lack of emotional anticipation and subsequent memory effect at the pre-stimulus phase. It is possible that the variability in the participants' evaluation or perception of negative pictures failed to form a strong mental representation of the negative stimuli at the anticipation phase. The use of high-arousal negative stimuli would serve two functions: first, cues and pictures will be more congruent in terms of negative arousal level as compared to the negative stimuli used in the previous experiment, which were mixed in arousal resulting in more variability in their subjective ratings. Second, the high arousal of stimuli might lead to vigilance/alertness instead of avoidance, just like in the threat of shock paradigm where participants anticipated a real threat of different intensity.

In the previous study in chapter 6, to be anticipated negative pictures varied in arousal as an equal number of low and high arousal pictures were used. It was assumed in that study that emotion is a unitary factor which contrast emotional and neural pictures without taking in to account that emotional stimuli can be differentiated according to the emotional intensity. Emotional intensity is the perceived strength of an emotional reaction to the stimuli. It was inferred from the findings of chapter 6 that varying arousal level of negative pictures diminished the effect of valence. Therefore, in this study only high-arousal negative pictures were selected.

If we find a Ps-Dm effect for the high-arousal informative cues, then:

i. Participants' arousal ratings would be consistent with the arousal rating of IAPS and GAPPED pictures
ii. The Informative cue condition will provide information about the intensity of the upcoming negative pictures
iii. The Non-Informative cue condition was manipulated to see whether the uncertainty about the upcoming stimuli might also lead to increased physiological arousal (Rubio et al., 2014). This physiological arousal might also contribute to enhanced memory. Therefore, Ps-Dm effects are also predicted for this condition.

7.3 Methods

7.3.1 Participants

Forty female participants (mean age = 19.45 years, SD = 1.85) were recruited from the Durham university participant pool or were volunteers recruited from other departments via flyers posted across campus. They were given an allocation of participant pool credits equivalent to the duration of the study or alternatively were remunerated £15 for their time. The basic selection criteria were the same as mentioned in chapter 6 section 6.3.4.

Participants went through the screening phase similar to the previous studies. Furthermore, out of forty tested participants, data from eight participants were excluded from analysis for reasons outlined in table 7.1 below.

Table 7.1: Table shows the number of participants excluded from the data analysis and Criteria for Removal

Total Removed	Codes	Reasons for removal
2	202, 233	These two files could not be used for analysis because of frequent eye movement and muscle artefacts or high impendence level (< 20 ohms).
6	205, 206, 219, 223, 229, 231	Data from these files could not be used for analysis because the memory performance means fewer than 12 trials were completed: a standard criterion for the number of trials specified for ERP studies

This table highlights the criteria that prevented the data from certain participants from being used in the studies.

Criteria for the EEG data analysis was the same as previous studies. Less than 12 artefact-free trials were excluded from the analysis. This criterion has been adopted from existing ERP studies on memory processes (Giulia Galli et al., 2011; Gruber & Otten, 2010; Padovani, Koenig, Brandeis, & Perrig, 2011; Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014). Thirty-two files were used for statistical analysis (mean age = 19.25 and SD = 1.83). Mean scores of the selected participants were in the normal range on the subscales of the DASS, (Depression; X = 1.51, SD = 2.03; Anxiety; X = 3.06, SD = 3.20 and Stress; X = 3.64, SD = 3.26).

7.3.2 Design

The experimental design of this study was similar to study 3 chapter 6, however, unlike Study 3, the cues and pictures were presented in random order.

7.3.3 Stimuli and material

One major modification was the use of the high-arousal negative pictures. In previous studies, high and low arousal pictures were selected from IAPS and Google Images. The picture selection criterion from IAPS and Google Images were the same as discussed in previous studies. However, the required number of high-arousal negative pictures was not available through the IAPS database. Therefore, additional pictures were selected from the Geneva Affective Picture Database: GAPED (Dan-Glauser & Scherer, 2011). This database was selected because it complements well with IAPS (Dan-Glauser & Scherer, 2011). The set of 730 GAPED pictures provides ratings on five scales; valence, two arousal scales (calm vs. excited and stimulated vs. relaxed), and internal (moral and ethically) and external (legal) acceptability of the content of pictures (see Appendix Q for full list of pictures with valence and arousal) However, for our study the picture selection was based exclusively on valence and arousal ratings. 110 high-arousal negative and 83 neutral pictures were selected based on valence and arousal ratings which ranged from 0 - 100, (0 = very negative, 100 = very positive and 50 = neutral point). A high score on arousal represented high arousal levels on two scales (calm to excited and stimulated to relaxed). The number of pictures selected from each database is given in table 7.2.

Table 7.2: Mean scores on arousal and valence of negative and neutral pictures selected from IAPS and GAPED database for the current study

Type of Pictures	**Database**	**Valence** *M (SD)*	**Arousal** *M(SD)*	**No of Pictures**
Negative	IAPS	2.05 (0.64)	6.49 (0.58)	190
	GAPED	14.93 (10.39)	70.24 (8.45)	110
				Total = 300
Neutral	IAPS	5.28 (0.68)	3.56 (0.71)	99
	Google	3.17 (0.20)	1.67 (0.21)	118
	GAPED	55.62 (6.19)	24.89 (7.94)	83
				Total = 300

In contrast to ERP study 3 in chapter 6 where the cue conditions (informative and non-informative) were blocked, in this study, the cues conditions were presented in random order. This was done to test the hypothesis that the Ps-Dm effects are observable when the cue conditions are randomized.

7.3.4 Procedure

See chapter 6, section 6.3.4 (page 142)

7.3.5 Electrophysiological data recording and processing

See chapter 5, section 5.3.5 (page 115)

7.3.6 Electrode Clusters

See chapter 5, section 5.3.6 (page 115)

7.3.7 Time bind for picture locked analysis

See chapter 5, section 5.3.7 (page 116)

7.3.8 Time bins for cue locked analysis

See chapter 6, section 6.3.8 (page 144)

7.3.9 Cue-locked Analysis

Based on careful visual inspection of the ERP data and a systematic analysis of a series of time windows, cue-picture epoch was analyzed in two sections. The first section includes the time duration for which the cue remained on the screen, which was ~0-1000 ms. It was done to examine the instant anticipatory response to the Informative (emotional and neutral) and Non-Informative cues. The second section includes the time epoch from 2000-3000ms when the cue disappears, and participants wait for the pictures to be displayed on the screen. This time duration was examined for sustained ERP activity related to anticipation.

Additional analyses were conducted for the examination of two ERP components identified as cortical measures of anticipation: Contingent Negative variation (CNV) and Stimulus-preceding Negativity (SPN) in the cue-locked time window.

ERPs extracted from these time windows were submitted to a 5 factor repeated measures ANOVA with factors of time (3 time windows), cue condition (Info-Cue vs. Non-Info), valence (negative vs. neutral), memory (remembered vs. forgotten), location (anterior vs. posterior) and laterality (left, right and midline). For the purpose of conciseness, the investigation's main focus is on the memory factor and the interaction between Cue × Valence × Memory interactions. Finally, topographical analyses were also performed for time windows in which a reliable Dm effect involving the above-mentioned location factors was obtained, in order to compare the scalp distributions of observed significant effects using normalized differences scores (McCarthy & Wood, 1985). The SPN component, which is a measure of affective anticipation, was investigated in this time window. Processing within the 200-300ms latency range reflects early stimulus discrimination and response selection processes. P3 components are more related to task relevance, motivational significance, arousal level, and the influence of these factors on mental resource/attention allocation (Olofsson et al., 2008).

7.4 Results

7.4.1 Behavioural Data Analysis

Statistical analysis of behavioural data and the rationale and definition of important terms is same as given in the behavioural data analysis section 4.3.4 in chapter 4 (page 113).

7.4.1.1 Recognition data: Hit-rates, R-hits, K-corr-hits and False Alarm

2 (Cue: Informative, No-Cue) × 2 (Valence: Negative, Neutral) repeated measures ANOVAs were conducted for HR, R-hits, FA and K-corrected separately. ANOVA for HR revealed a significant main effect of Valence F (1, 31) = 41.00, p = .001, η2p= .57, that is negative pictures were recognized more than neutral pictures (M_{HR}= .73, .60; *SEs* = .018, .022). The main effect of Cue condition and the Cue × Valence interaction were non-significant, (*F's* < 2.47, *P's* > .126). A separate ANOVA for R-hits also revealed a significant main effect of Valence, F (1, 31) = 50.84, p = .001, η2p= .621 that's negative pictures were remembered more than neutral pictures ($M_{R\text{-}hits}$ = .44, .28; *SEs* = .028, .022, respectively). Cue × Valence interaction and the main effect of Cue, (*F's* < 1.38, *P's* > .10). ANOVA conducted on K-corrected revealed a significant main effect of Valence, F (1, 31) = 4.60, p = .04, η2p= .129 that is negative pictures were remembered more than neutral pictures ($M_{K\text{-}corr\text{-}hits}$= .51, .45; *SEs* = .026, .025, respectively). Cue × Valence interaction and the main effect of Cue (*F's* < .182, *P's* > .135). Repeated measure ANOVA on false alarm (FA) showed a significant main effect of Valence F (1, 31) = 31.10, p = .001, η2p= .50, that is negative pictures were recognized more than neutral pictures (M_{FA}= .26, .16; *SEs* = .020, .017). The main effect of Cue condition non-significant, (*F< 1*). Cue × Valence interaction was significant for both cue conditions *Fs* (1, 31) = 38.43, 13.82, p = .001, η2p= .55, .30. The mean scores of False alarm rate for negative picture was greater than neutral for informative M = .28, SE = .019 and neutral M = .16, SE = .018, as well as for Non-Info cue condition M = .24, SE = .024 and neutral M = .16, SE = .020. However, the results show a stronger effect size for Informative cues compared to Non-Informative cues. Table 7.3 summarizes the results for Hit rates, R-hits, K-hits and false alarms (FA).

Table 7.3: Proportions of "Old" responses on the recognition memory test as a function of Cue condition, Picture Valence and memory performance

		Negative		Neutral	
Cues	Picture status	*M*	*SD*	*M*	*SD*
Informative	Hit-rates	.74	.10	.60	.13
	R-hits	.45	.16	.27	.11
	K-hits	.28	.13	.32	.10
	FA	.28	.11	.16	.10
Non-Informative	Hit-rates	.73	.11	.61	.13
	R-hits	.43	.16	.28	.14
	K-hits	.30	.12	.33	.12
	FA	.24	.14	.16	.11

Note= Proportion of Hit rates is the sum of the proportions of "Remember (R-hits)" and "Know" (K-hits) responses. The data, "K-hits" corresponds to the uncorrected know responses. The data for the corrected know responses K-corr = K/(1-R) is given in the text. False alarm rate is proportions of old responses to new pictures.

7.4.1.2 Pr index: Accuracy of recognition judgments for HR, R-hits and K-corr

The Pr score for overall recognition memory score (HR) is a combination of the proportion of R-hits and K-hits. ANOVA revealed that HR was not affected by Valence or Cue or by the interaction of Cue and Valence ($F < 1$). The *Pr* score for R-hits was also significantly higher for negative compared to neutral items M = .18 .11, SE = .032, .027 respectively, F (1, 31) = 5.72, p = .023, η2p= .156. The main effect of Cue and the Cue × Valence interaction was non-significant, (*F's* < .118, *P's* > .70). The Pr score for corrected K items was not affected by Valence or Cue or by the interaction between Cue and Valence ($F < 1$).

Overall, these results indicate that emotion enhances recognition when items are accompanied by a feeling of remembering (R) but not familiarity (K). Figure 7.1 illustrates these results.

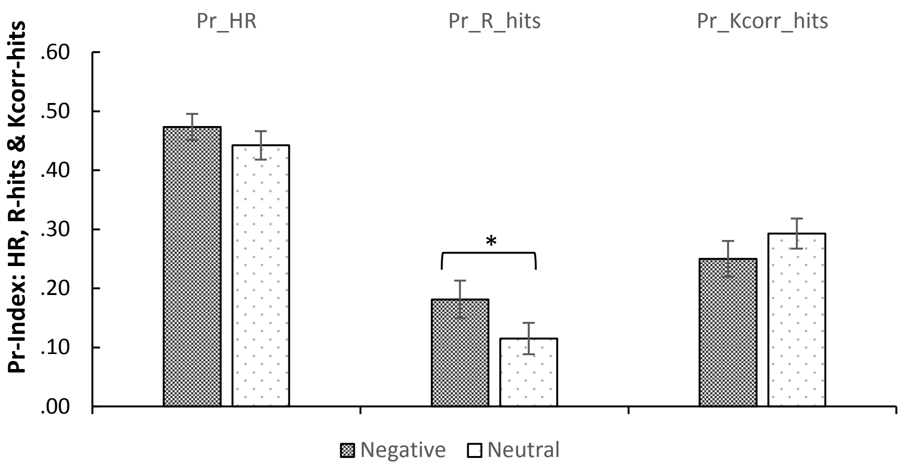


Figure 7.1: Recognition memory performance for Hit-rates, R-hits and K-corr-hits as a function of Valence .

*M*emory performance was measured with Pr, the difference between Hit-rates, R-hits, K-corr-hits and false alarm. Pr index varies from 0 -1 (no discrimination between studied and unstudied pictures to perfect discrimination). Error bars show the standard error of mean.

Recognition memory data was split by cue condition also to find the differences in the memory accuracy between valence categories. Simple main effects analysis of Pr index taking Hit-rates (HR) revealed a non-significant main effects of the Informative F (1, 31) = .709, p = .406, η2p = .022 (M: Info-neg= .46, SEs = .024; M:Info-neu= .43, SEs = .026) as well as Non-Informative cue condition were non-significant (1, 31) = 2.98, p = .094, η2p = .088, M:Info-neg= .49, SEs = .025; M:Info-neu= .45, SEs = .025.

Simple main effects analysis of Pr index of 'remembered' responses (R-Hits) revealed a just significant main effect of the Informative cue condition, *F* (1, 31) = 4.12, *p* = .05, *η2p* = .117. Overall mean scores on Pr-Index were higher for negative ($M_{Info\text{-}neg}$= .18, *SEs* = .033) as compared to neutral pictures ($M_{Info\text{-}neu}$= .11, *SEs* = .027). A significant main effect was also obtained for Non-Informative cue condition, *F* (1, 31) = 5.27, *p* = .029, *η2p* = .145, ($M_{Info\text{-}neg}$= .19, *SEs* = .034; $M_{Info\text{-}neu}$= .11, *SEs* = .029).

Pr index of corrected 'Know' responses (Kcorr-hits) was also put to the simple main effect analysis. Main effects of the Informative *F* (1, 31) = 3.78, *p* = .061, *η2p* = .109, ($M_{Info\text{-}neg}$= .21, *SEs* = .035; $M_{Info\text{-}neu}$= .29, *SEs* = .025) as well as Non-Informative cue condition were non-significant (1, 31) = .406, p = .529, $\eta 2p$ = .013, $M_{Info\text{-}neg}$= .28, SEs = .031; $M_{Info\text{-}neu}$= .30, SEs = .029 (see figure 7.2).

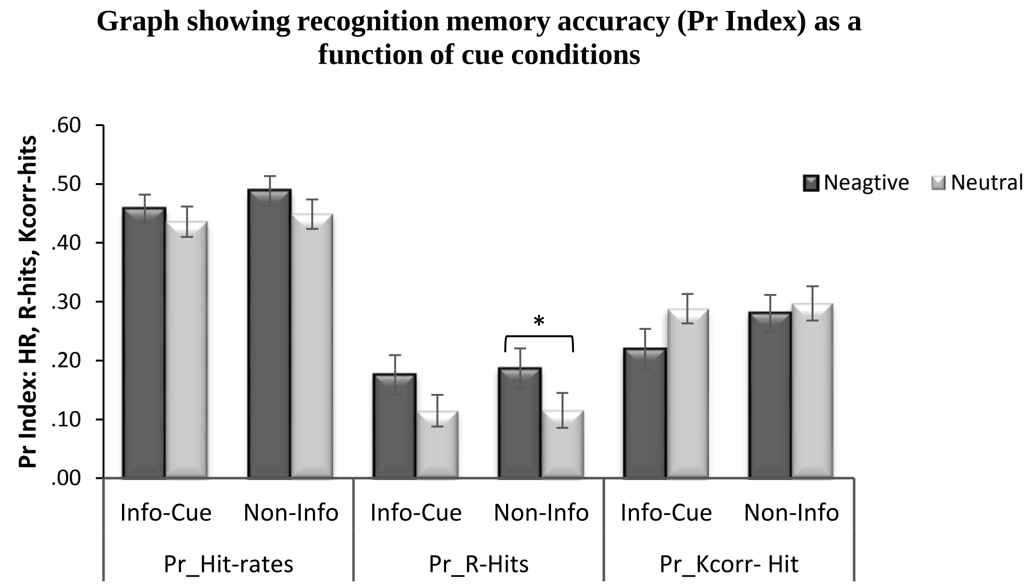


Figure 7.2: Recognition memory performance for Hit-rates, R-hits and K-corr-hits as a function of Cue condition .

Figure shows that only Non-Informative cue condition resulted into difference between negative and neutral. Error bars show the standard error of mean.

7.4.1.3 Valence rating by participants across cue conditions

Average arousal ratings obtained from the participants at the encoding phase were entered into a repeated measures ANOVA with factors of Valence (negative, neutral) and Cue type (Info-Cue & Non-Info cues). There was a significant main effect of Valence, F (1, 31) = 557.58, p = .001, η2p= .94, indicating that negative pictures (M = 13.74, SE = 0.60) were rated as more emotionally arousing than neutral pictures (M = 1.61, SE = 0.46). Critically, the main effect of Cue condition, F (1, 31) = 3.09, p = .001, η2p= .09 and a Cue × Valence interaction was significant (1, 31) = .97, p = .001, η2p= .46.

7.4.1.4 Reaction time

Participants' reaction times to picture-rating was submitted to a repeated measures ANOVA with factors of Cue × Valence × Memory. None of the main effects were significant. The interaction between Cue × Valence × Memory was also non-significant F (1, 31) = .096, p = .758, η2p= .003. These findings revealed that both cue conditions were similar in regard to the efficiency of processing of stimuli.

7.4.2 Cue-locked ERP Analysis

7.4.2.1 400-1000ms: Ps-Dm effect

To investigate the ERP data for the pre-stimulus subsequent memory effect (Ps-Dm effect), the 400-1000 ms time window was further divided into three time windows (400-600) (600-800) (800-1000). A significant main effect of Cue condition, F (1, 31) = 5.13, p = .031, η2p= .142 indicated a larger positivity for the Info-Cue (M = 5.64, SE = 1.88) compared to the Non-Info Cue (M = 2.80, SE = 1.63). The main effect of Valence, F (1, 31) = 17.79, p = .001, η2p= .365 also showed greater positivity for the negative items (M = 6.52, SE = 1.75) than for neutral items (M = 1.92, SE = 1.72). A significant Memory effect, F (1, 31) = 4.20, p = .049, η2p= .119, revealed that waveforms for forgotten items were more positive (M = 5.41, SE = 1.72) compared to remembered ones (M = 3.03, SE = 1.76).

The only significant interaction which involved memory was Time × Valence × Memory × Anteriority × Laterality F (1, 31) = 2.83, p = .027, η2p=.084. A subsidiary analysis revealed a significant Valence × Memory × Anteriority × Laterality interaction F (2, 62) = 4.84, p = .011, η2p=.135, for the 400-600ms time window. To better understand the Memory × Anteriority × Laterality interaction, separate ANOVAs were conducted for negative and neutral stimuli. The Memory × Anteriority × Laterality interaction was significant for negative stimuli F (2, 62) = 3.97, p = .024, η2p= .114, but not for neutral stimuli, F (2, 62) = .914, p = .406, η2p= .029. The main effect of memory was not significant at any of the scalp site (F's < .871, P's > .358) and Laterality (F's < .311, P's > .581).

7.4.2.2 1000-3000ms: Sustained Anticipatory activity

This large time window was further divided into two-time windows: 1000-2000ms and 2000-3000ms. ERP extracted from these two time windows were submitted to the repeated measures ANOVA with factors of Time (2 time windows), Anticipatory cue conditions (Info-Cue vs. Non-Info), Valence (negative vs. neutral) memory (remembered vs. forgotten) Anteriority (anterior vs. posterior) and Laterality (left, right vs. midline).

ANOVA revealed a significant interaction for Time × Valence × Memory × Anteriority, F (2, 62) = 4.62, p = .039, η2p= .130. Subsidiary analyses revealed a significant interaction for Valence × Memory × Anteriority F (1, 31) = 8.90, p = .006, η2p= .223 during 2000-3000ms time window. Separate ANOVAs computed for Valence revealed a significant interaction for neutral stimuli F (2, 62) = 7.79, p = .009, η2p= .201, but not for negative stimuli F (2, 62) = 2.02, p = .165, η2p= .061 (see figure 7.3 b). Amplitude for the forgotten waveforms tend to be higher with a negative deflection compared to remembered (M = -77.38, -98.17, SEs = 21.73, 22.60) at anterior scalp site only, F (1, 31) = 3.78, p = .061, η2p=.109. This effect was totally absent at posterior site, $F(1, 31) = .248$, $p = .622$, η2p=.008 (see figure 7.3 a). ANOVA revealed a just significant main effect of Memory $F(1, 31) = 4.11$, $p = .05$, η2p= .117, indicating an overall positivity for subsequently remembered compared to subsequently forgotten items. A non-significant interaction was found for Time × Cue × Valence × Memory × Anteriority, $F(2, 62) = 3.94$, $p = .06$, η2p=.113.

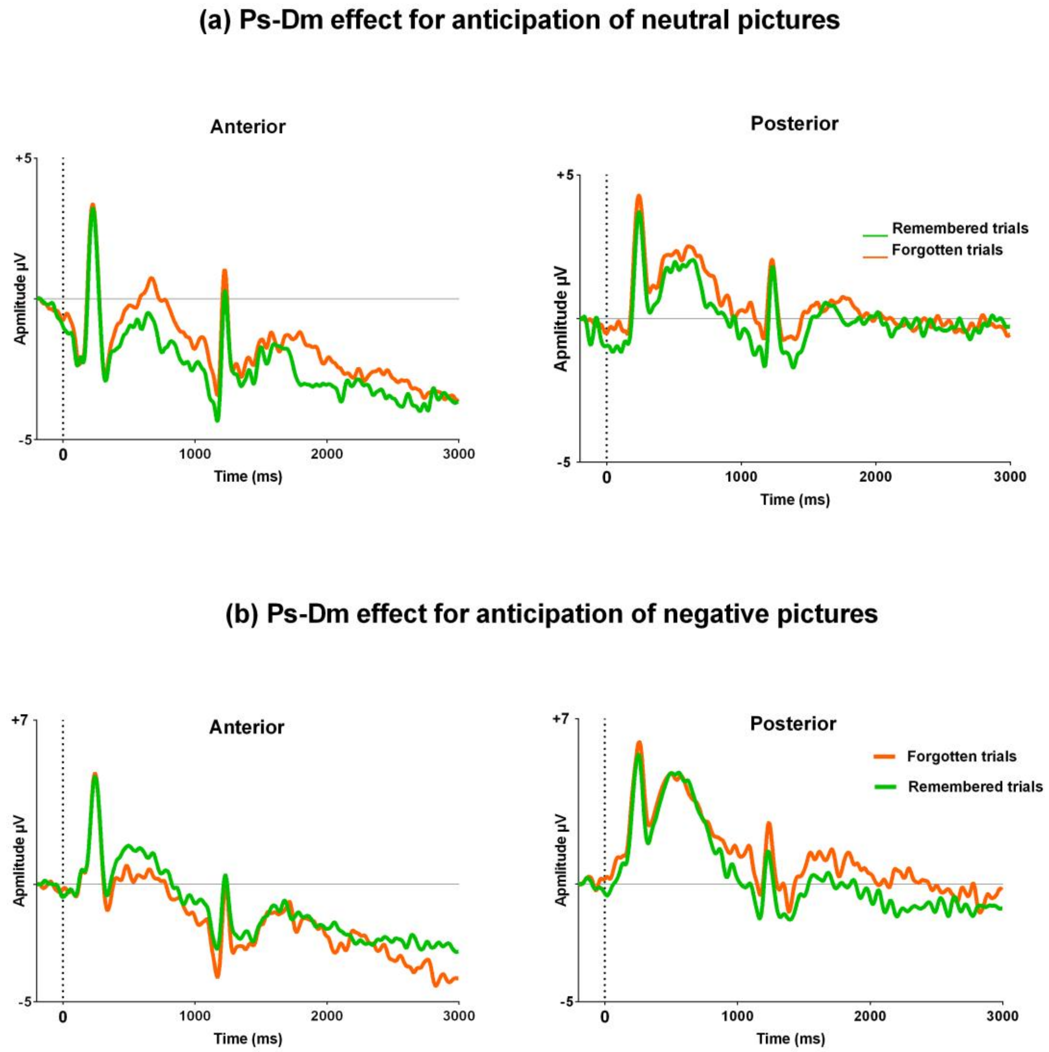


Figure 7.3: ERP waveform representing cue related encoding activity across picture valence for 1000-3000ms time bin.

a) ERP waveform plotted on anterior and posterior electrodes for anticipation related neural activity for neutral pictures according to subsequent memory (Remembered vs. Forgotten items). Amplitude in microvolts is on the y-axis and time in milliseconds is on the x-axis.

b) ERP waveform plotted on anterior and posterior electrodes for anticipation related neural activity according to subsequent memory (Remembered vs. Forgotten items) for negative pictures Amplitude in microvolts is on the y-axis and time in milliseconds is on the x-axis.

7.4.2.3 SPN 2800-3000ms

The Cue × Valence interaction was non-significant F (1, 31) = .200, p = .658, η2p=.006. These findings could not provide evidence of emotional anticipation at work here.

7.4.3 Picture- Locked ERP Analysis

7.4.3.1 50-100 ms: P1

The P1 component, which is considered an index of selective attention, appeared to be significant for Cue conditions only at Cz, F (1, 31) = 4.95, p = .03, η2p=.138, where the Info-Cue formed a negative-going waveform (M = -2.03, SE = .362) compared to the Non-Info cue condition (M = -1.58, SE = .317).

7.4.3.2 150-200 ms: P2

P2 is associated with arousal-related positivity. Here, the main effect of Valence was significant at Pz, F (1, 31) = 18.97, p = .001, η2p= .38, showing an overall larger positivity for negative (M = 1.13 , SE = .837) over neutral pictures (M = -.049 , SE = .827).

7.4.3.3 200-300 ms: N2

A significant Cue × Valence × Memory interaction was found, F (2, 62) = 6.27, p = .018, η2p=.168. ANOVAs separated by cue condition revealed a significant Valence × Memory interaction for the Info-Cue F (2, 62) = 4.80, p = .036, η2p= .134 but not for the Non-Info cue, F (2, 62) = .196, p = .379, η2p= .025, condition. However, memory effect was further non-significant for negative and neutral pictures.

7.4.3.4 300-400 ms: P3

Cue-related main effects were also found to be significant at Cz, F (1, 31) = 5.08 p = .013, η2p=.141 for Non-Info cues (M = -3.49, SE = 1.38) relative to Info-Cue cues (M = -4.21, SE = 1.32).

7.4.3.5 400-1000ms-Post-stimulus Dm effect

A significant main effect of memory was found F (1, 31) = 14.43, p = .001, η2p=.318 indicating a larger positivity for subsequently remembered items (M = 19.49, SE = 4.10) compared to subsequently forgotten items (M = 13.11, SE = 3.65). The main effect of Valence, F (1, 31) = 75.87, p = .001, η2p= .710, indicated larger positivity for negative items (M = 28.91, SE = 4.62) relative to neutral items (M = 3.64, SE = 3.40). However, the Cue × Valence × Memory × Anteriority × Laterality interaction did not reach significance, F (1, 31) = .048, p = .953, η2p= .002.

7.5 Discussion

The main question under study was that if the anticipation of high-arousal negative stimuli modulates the memory related components at anticipatory phase (~0-3000ms). It was hypothesized that anticipation of highly arousing emotionally negative stimuli would affect ERPs of subsequent memory at the anticipatory phase. The pre-stimulus Dm effect was analyzed at three-time points in a cue-epoch of 3000ms time duration. First, for the display duration of the cue on the screen; second, during sustained anticipatory neural activity when cue disappears and third, 200ms prior to the onset of pictures for Stimulus Preceding Negativity (SPN) which is taken as an index of emotional anticipation. They will be discussed in the same order in this section.

Since two type of anticipatory cues were presented: Informative and Non-Informative. To be anticipated emotionally negative stimuli were all high arousal negative pictures. For the cue display duration (~0-1000ms) findings revealed a reliable, significant main effect of memory for negative picture only. In particular findings showed that regardless of the cue conditions the amplitude of the remembered negative picture was higher than neutral during 400-600ms time widow. However, these findings appeared without any scalp related topographical differences.

Several inferences can be made from these findings: one, the information content of the cue is not necessary to elicit memory related ERP effect at anticipatory phase. Since, the emotional memory effect was found for Informative and Non-Informative cue condition,therefore, the preparatory processes explanation reported in previous studies (Galli et al., 2014; Galli, Wolpe, et al., 2011) cannot be generalized to the condition where preparation, specific to attend negative pictures was absent. These findings suggest that when the cues are present, it does not matter if they provide specific information about the upcoming stimuli or not, it does influence memory encoding. Thus, these findings showed that Ps-Dm effect is not limited to the informative cue condition which provide very specific information about the upcoming stimuli. It was previously proposed that the Ps-Dm effect in the Non-Informative cue condition might reflect random fluctuation in attention. However, if this were the case then, there might not be a pattern of neural activity which is more than a chance. Therefore, it is possible to exclude an indirect influence of random neural activity as an explanation of significant Ps-Dm effect for Non-Informative cue condition. A more comprehensible and plausible explanation comes from a 'Predictive Anticipatory Activity'(PAA) theory proposed by Mossbridge et al., (2014). The basic idea is that our physiology has the capacity to anticipate unpredictable negative events before they occur and may influence decisions and memory formation (Mossbridge et al., 2014). The Ps-Dm effect in the Non-Informative cue condition could possibly be a PAA phenomenon. By definition, PAA refers to statistically reliable difference between physiological measures (e.g. EEG/ERP or skin conductance) recorded few seconds before unpredictable emotional events occur in comparison to the neutral event. The Ps-Dm effect in Non-Informative cue condition might be an unconscious phenomenon that seems to be a time-reversed reflection of the physiological response to an imminent emotional stimulus (Mossbridge et al., 2014)

It was hypothesized that high arousal of the emotionally negative pictures would modulate emotional memory encoding at anticipatory phase. Selection of emotionally intense negative pictures was guided by the findings of the study reported in chapter 6 in which pictures varied in emotional intensity. It was concluded that a non-significant Ps-Dm effect might be because of the variability in the intensity of the emotional pictures. Therefore, in this study, it was assumed that anticipation of the emotionally intense negative pictures would yield significant Ps-Dm effect. Findings of the current study provide evidence to support this assumption. These findings are further supported by those studies in which only high-arousal stimuli were used to investigate pre-stimulus subsequent memory effects (Greenberg, Carlson, Rubin, Cha, & Mujica-Parodi, 2014; Mackiewicz et al., 2006b).

In the current study (as well in all the studies of this project), the cue remained on screen for ~0-1000ms out of ~0-3000ms anticipatory phase and disappeared for the rest of the epoch from 1000-3000ms. Selection of this epoch-duration was in-line with the literature on cortical measures of anticipation (Boxtel et al., 2004; Brunia, van Boxtel, & Böcker, 2011; Chwilla & Brunia, 1991). Notably, significant Ps-Dm effect for both cue conditions elicited in the 400-600ms time window. This window is important as it was the time period when the cue was still on the screen during the anticipatory phase. It was expected that the anticipatory attention to the emotional pictures will sustain for 1000-3000ms time window till the onset of pictures. However, the outcome was reversed that is, in place of sustained Dm effect for emotional memory, Dm for the anticipation of neutral pictures was significant. In particular, the amplitude for the forgotten waveforms was higher than the remembered with a negative deflection over anterior scalp site during 2000-3000ms time window. It appeared the anticipatory attention for the emotionally negative pictures that cues formed, could not be maintained in the working memory (when the cue disappeared during 1000-3000ms) due to lack of vigilance (or 'Vigilance Decrements'). Vigilance is the ability of the organism to maintain its focus of attention and to remain alert over a prolonged period of time (Warm, Parasuraman, & Matthews, 2008). Since sustained attention is effortful and vigilance decrements occur due to resource depletion, cognitive overload, boredom, lack of task engagement contributes to lapses in sustained attention (Esterman, Noonan, Rosenberg & DeGutis, 2013).

Another possible interpretation of reverse Dm Effect at two anticipatory phases is that the anticipatory attention is somehow related to the presence of the cue on the screen. That is the Ps-Dm effect is more related to the bottom-up processing of cue stimuli than top-down modulation. This pattern of results corroborates well with the findings reported in the previous ERP studies on Ps-Dm effect (Galli, Griffiths, et al., 2012; Galli, Wolpe, et al., 2011). These studies were designed in a way that the pictorial cues remained on the screen for the whole duration (~0-1400) of the anticipatory phase and disappeared only 100ms before the picture onset. Moreover, these studies did not provide a comparative statistical analysis of both time window: 0ms-1400ms verses 100ms, therefore, it is unknown what happened 100ms before picture onset. On the other hand, it is frequently reported in ERP literature on anticipation that index of emotional anticipation (SPN) is only elicited 200ms before the emotionally salient picture onset (Böcker et al., 2001; Buodo et al., 2012; Catena et al., 2012b; Masaki, Yamazaki, & Hackley, 2010; Poli, Sarlo, Bortoletto, Buodo, & Palomba, 2007). Considering the literature, it was expected to find a Ps-Dm effect during the 1000-3000ms time window and 200ms prior to the occurrence of imminent emotional stimuli. However, a nonsignificant Ps-Dm in both these windows shows that emotional anticipation and memory formation is somehow related to the presence of the cue than its perceptual meanings. In the absence of this sort of analysis in Galli et al. (2011), it is difficult to make any conclusion regarding the sustained anticipatory activity when the cue disappears from the screen. Relying on the current data, it appeared that Ps-Dm effect is confined to the presence of the cue on the screen only.

Two conclusions can be drawn on the basis of the current findings: one, the Ps-Dm effect is not associated with the memory encoding rather it just shows the general preparation to attend to some imminent stimuli which might occur with or without the knowledge of anticipated stimuli. Second, preparatory process hypothesis is not the only explanation of Ps-Dm effect for the reason that similar findings can also be obtained for Non-Informative cue conditions.

Despite these neutral memory-related reactivations at the pre-stimulus phase, we could not find the emotional memory effects after the picture display (post-stimulus phase). These findings are in line with Galli et al. 2011, study which did not find valence-specific memory differences in the cueing paradigm in which they found the Ps-Dm effect. On the other hand, previous studies on EEM, which did not investigate the role of anticipation found the well-established Dm effect in response to emotional pictures prominent over frontocentral or parietal scalp sites over the 600-800ms classic time interval (Kensinger, 2009; Mather, 2009; Post et al., 1998). One possible explanation for the absence of EEM in the paradigms which used anticipation might be due to the activation of preparatory responses which exert an influence on subsequent encoding and thereby compete with the effects of emotion on encoding (Gruber & Otten, 2010; Yick et al., 2015). The behavioral data was tested to have an idea of memory accuracy under Informative and Non-Informative cue conditions. Findings showed that regardless of the cue condition participants recollection memory was better for negative than neutral pictures.

Understanding the Ps-Dm effect under Non-Informative Cues have a certain useful implication. For instance, it will be a highly adaptive skill, if individual are able to prepare themselves without experience and perceptual cues to deal with emotional events by activating the sympathetic or central nervous system before the occurrence of these events. Future studies might focus on the most engaging task related to the anticipated stimuli to investigate its effect on the sustained anticipatory period. The degree of the information processing should also be reduced by minimizing the number of factors or cues.

7.6 Conclusion

To sum, the findings of the current ERP study demonstrated dissociable neural processing associated with distinct stages in anticipation of emotionally negative stimuli. Findings revealed a Ps-Dm effect regardless of cue condition during 400-600ms time window. These findings mirror the behavioural findings reported in chapter 4 and suggested that the presence of the cues is important than its informative content. Ps-Dm effect was not found for emotionally negative stimuli in the time window from 1000-3000ms which signify that Ps-Dm effect is more related to the bottom-up processing of the stimuli as it was seen only for the time duration when the cue was present on the screen and diminished when the cue disappeared. This pattern of result also suggests that the anticipation is not a unitary process; rather it has distinct temporal stages which are supported by the dissociable neural mechanism. As a first electrophysiological evidence, these findings highlight the need for the further research that acknowledges the importance of memory formation in these distinct temporal stages of anticipation.

Chapter 8: General Discussion

8.1 Overview

The central premise of this thesis is to determine what evidence supports the predictions that fore-knowledge about an event is not essential to achieve a pre-stimulus subsequent memory effect (Ps-Dm effect). Findings from one of the series of four experiments provided support in favour of the hypothesis. However, results of the other studies could not provide strong evidence for the prediction. This chapter summarizes the findings, strengths, limitations and opportunities for further research. The conclusions of these studies are also interpreted in terms of real-world implications, and how this work can be applied to the other areas of research.

8.2 Anticipation and emotional memory

Humans are built with adaptive brains that help them survive in various environments. One type of adaptability is the ability to remember events, and anticipate ones, especially if they are emotional. This adaptation is critical for functioning across a broad array of daily activities, ranging from basic cognitive operations required to efficiently perform simple tasks, to complex, future-oriented emotional processes that support motivated behaviour.

Anticipatory processes enable us to prepare for, and consider, the potential consequences of forthcoming events, rather than respond to such events in a purely reactive manner. Therefore, anticipation is as much an adaptive behaviour as is memory formation.

Anticipatory responses can be measured via the Event-Related Potential (ERP), which is a useful tool for investigating early anticipatory responses. The ERP can provide a direct cortical measure of anticipatory processes on the scale of milliseconds to seconds.

Anticipation and memory are related cognitive processes, each one drawing from the other in a cyclical manner. To understand this relationship between anticipation and emotional memory, each study of this thesis was designed to allow differences between remembered and forgotten emotional and neutral pictures to be analysed. The images, both emotional and neutral, were examined at the following levels:

- Pre-stimulus
- Post-stimulus
- Behavioural

The study also aimed to rule out whether behavioural results are dissociable from pre- and post-stimulus anticipatory processes, which are a component of the anticipation model of emotional memory (Bernheim & Thomadsen, 2003). Additionally, Galli, et al.'s 2011 study did not contain a control condition in the experiment against which ERP findings were compared. We determined that this was a weakness in the study, and chose to address the issue. In the absence of a baseline condition in the pre-stimulus phase, it is difficult to reliably determine if the observed difference between remembered and forgotten waveforms is an index of the Ps-Dm effect. At a behavioural level, this question was addressed in the studies, and at a neural level, was dealt with in the follow-up ERP study.

8.3 Behavioural findings

The behavioural analyses of the studies were aimed at answering whether or not emotional memory is enhanced when cues provide information regarding the valence (negative or neutral) of pictures.

The cues used were of three conditions:

- Informative
- No-cue
- Non-informative

These three conditions differ in terms of the information they convey to participants regarding the emotional nature of upcoming pictures. The Informative cues indicated that the upcoming pictures would be of some sort of emotional valence while the Non-informative cues did not reveal the emotional valence of the pictures. The No-cue condition did not provide the participant with any kind of information regarding the type of picture they would be shown. Once these trials were completed, memory recognition was tested. Findings revealed that emotional memory is *not* modulated by any type of anticipatory cues. That is, anticipating the emotional valence of a picture did not impact memory encoding for that picture once recognition memory was tested.

Participants had to rate the valence of each picture presented using the Self-Assessment Manikin (SAM) rating scale. They were instructed to prepare themselves for the picture mentally prior to the cue being displayed. The cues were always congruent with the picture. Moreover, participants were not informed about the subsequent memory test.

Previous studies have largely ignored the behavioural outcome of different types of anticipation on emotional memory enhancement (Galli et al., 2014; Galli, Choy, et al., 2012; Galli, Wolpe, et al., 2011). These studies only reported an ERP indicator (Ps-Dm effect) without a behavioural outcome and showed a difference in neural activity between remembered and forgotten pictures during the time period when participants were waiting for the picture to appear on the screen. One potential reason for the absence of a corresponding behavioural effect might be because the particular studies addressed the relevant question only.

The current project initiated by exploring if the significant pattern of neural activity occurs with or without a corresponding change in overt behaviour. The study in Chapter 4 focused solely on the behavioural outcome of cue manipulation: comparing the three types of anticipatory conditions for emotional memory. In that study, the recognition memory index (Pr) or Remembered judgement showed that emotional memory was significantly enhanced under informative and non-informative cue conditions, as compared to the No-Cue condition. However, the effect size was stronger in Informative cue conditions, as compared to the Non-Informative cue condition. The behavioural findings of the subsequent ERP studies of this project could not find a corresponding change at the behavioural level. That is, in these studies the only prominent finding was the effect of valence which signified that emotionally negative pictures were recognized with greater accuracy than neutral pictures regardless of cue conditions. However, the manipulation of the cue did not differentially affect the valence. Even in the third study (chapter 7), the anticipation of high arousal pictures did not modulate the accuracy of recognition memory differently for informative and Non-Informative cues. A possible explanation for the non-significant modulatory effect of cue manipulation on memory might be that pre-stimulus effects are also dissociable from the behavioural outcome.

8.3.1 Valence ratings

Self-reported emotional response to the negative and neutral pictures was obtained from the participants using a self-assessment manikin SAM rating scale in all the ERP studies. Its purpose was to see how participants evaluate emotional content. In the first two ERP studies, low and high arousal pictures were presented. It was observed that participants rated low arousal negative pictures as negative when no cue was presented. However, when the cue was non-informative, participants' ratings were less negative compared to the informative cue condition. When the pictures were all high arousal, then there was less variability in the rating of negative pictures. These analyses tested the assumption that uncertainty increases the arousal level . Therefore, participants would rate low arousal negative pictures as even more arousing. There was inconsistency in the findings as one study (chapter 5) supported the prediction while the other reported in chapter 6 could not support this prediction. The ratings of pictures were consistent with the valence rating in chapter 7 in which all high arousal pictures were used. These findings suggest that variation in ratings of high and low arousal pictures by participants resulted in non-significant Dm-effect in study 5 and 6.

8.3.2 Reaction time

All the experiments were designed in such a way that the participants had to rate the valence of the pictures as to how unpleasant or pleasant or neutral they made the participants feel. This rating task does not require a quick reaction from the participants. It was done considering ERP methodology related to anticipation (S1-S2 paradigm) where the anticipation of emotional stimuli is considered motivationally significant itself and therefore requires no quick motor response. It was hypothesized that participants would respond quickly to the pictures when they were informed about the valence of the picture compared to the condition which did not provide cue information. The idea was that foreknowledge helps in preparation, which influences a shorter reaction time. Findings revealed no differences in reaction time for any factor: cue, valence or memory. These findings suggest that reaction time difference might only be observed when participants get explicit instructions about the response. Moreover, on the basis of results from all studies it appeared that reaction time is linked to Stimulus-preceding Negativity (SPN). This point will be discussed in detail while discussing the finding of SPN analysis.

8.4 ERP Findings

8.4.1 Neural activity preceding cue (Pre-stimulus Dm-effect)

In previous studies on the Ps-Dm effect, the conceptualization and modelling of anticipation have been treated as a single unitary process. That is, in these studies, the cue remained on the screen for the whole anticipatory period, such as ~0-1500ms in the case of Galli, et al., (2011) study. The total anticipatory period was ~0-3000ms in all the ERP studies of this thesis. However, the cues remained on the screen for only ~0-1000ms. It was done for two reasons: one, specifically to keep the constructs and methodology closer to what is conventional in electroencephalography literature on anticipation at a descriptive level. Two, it allowed the investigation of different temporal stages of anticipation (e.g., ~0-1000ms and 1000ms-3000ms) statistically.

In each study, a different trend was observed. When the Informative cue condition was paired with the No cue condition, only an informative cue condition influenced memory, regardless of the valence of the pictures (chapter 5). It was predicted that Ps-Dm effect specific to the anticipation of emotional stimuli would be found for Non-informative cue conditions (chapter 6). The Ps-Dm effect was found under Non-Informative cue conditions during the 600-800ms period, surprisingly, for the anticipation of neutral pictures, but not for emotional ones. An important factor accounting for these findings was the emotional valence of the pictures that participants anticipated. It might be the case that the subject anticipated a much stronger emotional valence when they were forewarned, and then the picture wasn't that emotionally arousing to them, and so there was no effect. However, this study did not inquire from participants if they thought the pictures' emotional valence matched their expectations. The inclusion of high and low arousal pictures had two implications for the study: the anticipation of neutral pictures met the participants' expectation regarding the anticipated item.

In contrast, due to the inclusion of high and low emotionally negative pictures, participant's anticipation did not meet their expectations. Moreover, in chapter 6's study, high and low arousal pictures could not be analysed separately due to an insufficient number of trials in each arousal category and the study was not designed initially with an aim to compare data on arousal level. Therefore, it is possible that the participants anticipate neutral pictures differently from the emotionally negative pictures. That is, they have different expectations for negative versus neutral images. One possible explanation for this finding might be that the participants found the evaluation of the neutral stimuli more consistent as compared to the evaluation of emotional stimuli. That is, the emotional valence of neutral images were more consistent, as compared to the emotional valence of negative images, which may have been more varied. However, when the next study was designed using all high-arousal emotionally-negative pictures to make it more uniform for participants, the findings were different. That is, Ps-Dm effect was significant for not only Informative cues but also for Non-informative cues (chapter 7). This is a key finding for the anticipatory phase: Memory-related components are only affected when the cue is presented with high emotional arousal stimuli. This is regardless of whether or not the cues are informative and non-informative (Bauch, Rausch, & Bunzeck, 2014; Lobanov, Zeidan, McHaffie, Kraft, & Coghill, 2014)

The Ps-Dm effect was also investigated in the sustained anticipatory phase, resuming from 1000ms -3000ms, which ends at the display of the picture stimulus. As mentioned earlier, that cue remained on the screen for the 0ms- 1000ms interval only; the rest of the time period was investigated for sustained anticipatory neural activity after the cue was removed. Findings of the two ERP studies revealed Ps-Dm effect for the anticipation of the neutral picture when the cues were informative. However, these results were not accompanied by any significant scalp distribution (Chapter 5 & 6). No evidence of Ps-Dm effect was found for the sustained anticipatory period in the third study too (chapter 7) where the participants anticipated high-arousal negative pictures. One possible reason for null effects for emotion-related anticipatory activity may be due to individual difference in habitual use of emotional regulation strategies, especially considering all the participants were healthy adults and screened for the psychiatric symptoms. Therefore, they might have used a cognitive disengagement or distraction strategy which leads to reduced emotional sensitivity for the upcoming stimuli. Similar findings were obtained in a study where a reduced pupil dilation was observed when participants were not explicitly asked to use emotion regulation strategies (Vanderhasselt, Remue, Ng, & De Raedt, 2014).

Another factor that might explain these findings is the time interval between cue and picture display, which could not be manipulated in the current project. Therefore, the current experimental design did not allow the use of short and long time intervals, to explore if the cue picture time duration is the modulatory factor for Ps-Dm effect. Future experiments might take cue-picture time interval as an experimental variable.
These findings can be explained in the light of the random fluctuations hypothesis proposed initially for the Ps-Dm effect under Non-Info cue condition. This hypothesis suggests that Ps-Dm effect is not actually related to memory encoding rather it results due to the variation in attention commonly observed in the pre-stimulus phase of any ERP study. However, further research is needed to confirm this explanation proposed by this hypothesis.

It can be concluded on the basis of the findings of these studies that preparation does not always leads to arousal. Rather, when participants are prepared for viewing emotional pictures, they might have used implicit emotion regulation strategies during that anticipatory time period. This might be one mechanism working behind the non-significant Ps-Dm effect for informative cues compared to the non-informative cues conditions. Mental preparation or motor preparation might be different. It was observed in these experiments that mental preparation reduced sensitivity towards upcoming emotional stimuli. This sort of mental preparation is a significant marker of well-being, and a failure in preparation leads towards anxiety-like behaviour, which is observed in clinical populations (Girodo, et al., 1978; Derakshan & Eysenck, 2009).

8.4.1.1 Contingent Negative Variation (CNV)

The primary goal of this project was to investigate if anticipation boosts memory formation under different types of cues condition. However, use of ERP technique also allowed us to do some important analyses that help in explaining the relation between anticipation and emotional memory. One such analysis was done to investigate cue-related neural activity, which prepares an individual for a task. This activity is named the Contingent Negative Variation (CNV). It builds up during the Cue-Picture (S1-S2) time interval to get ready to respond to S2. However, it is considered to be related to motor preparation and to S2. Preparatory activity can be observed in any ERP study, before the occurrence of stimuli. Therefore, baseline correction is applied to filter out this anticipatory activity, and in some studies, randomization of trial type and stimulus sequence helps in dealing with this activity. However, in this current project, manipulation of anticipatory activity is the focus and locked to cue presentation.

No specific hypothesis was formulated due to the exploratory nature of CNV in the current investigation. CNV related activity in the current project was focused in the time window where the cue remained on the screen ~0-1000ms specifically. The analysis focused on the main effect of the cue and its interaction with valence or memory. Findings from the three ERPs converge on the point that Informative cues-related main effects were significant with more positive-going deflection, compared to No-Cue and Non-Info cue conditions. However, latency-wise, all the studies provided different results. For instance, the anticipation of negative pictures under informative cue conditions appeared with a more positive-going deflection at midline as compared to the right and left the side of the scalp during the 350- 600ms time window (chapter 5). Informative cues influenced memory during 600-800ms time window in chapter 6. In the study (chapter 7) involving high-arousal stimuli, cue-related ERP activity started quite early in the 200-300ms time window. These findings suggest that CN is influenced by the high arousal of anticipated negative stimuli. These findings are further supported by a number of other studies in which CNV was influenced due to the presence of high-arousal stimuli (Howard et al., 1992; Klorman and Ryan, 1980; Simons et al., 1979).

8.4.1.2 Stimulus-Preceding Negativity (SPN)

This project is an attempt to corroborate the basic concept and methodology of cortical measures of anticipation into the research questions under investigation. One such effort is the investigation of Stimulus-Preceding Negativity (SPN). SPN is an ERP component, which is related to emotional anticipation (Schupp, et al., 2003; van Boxtel & Böcker, 2004). This ERP component is conventionally captured in the time window just 200ms before picture display. It is assumed that if the upcoming stimulus is emotional in nature, the neural activity in this time window will be different from the neural activity if the upcoming stimulus is neutral. This component, i.e. SPN was found to be non-significant in all the ERP studies of the current project.

One may infer that the Non-significant SPN in studies of chapters 5 and 6 may be because the pictures were not highly arousing stimuli. A number of previous studies obtained significant SPN when intense emotional pictures, such as violent, fearful and erotic images, were used (Howard et al., 1992; Klorman and Ryan, 1980; Simons et al., 1979). However, the study reported in chapter 7 used only highly arousing stimuli, but the findings were the same, that is, a non-significant SPN. Another factor reported in the literature is monetary feedback, or prior task performance is (Kotani et al., 2003; Ohgami, Kotani, Hiraku, Aihara, & Ishii, 2004) which could not be manipulated in the current research but could have resulted in a significant SPN. Evidence for the usefulness of this factor comes from the interpretation of the current results.

Surprisingly, in all the ERP studies, reaction times, as well as SPN, were all non-significant. This pattern suggests a link between the reaction time measure (behavioural measure) and SPN (ERP component). It is important to mention here that in the anticipatory paradigm emotional stimuli are taken as motivationally significant. Therefore, its ERP index-SPN does not require a motor response to the stimuli.

SPN is also known as a non-motor preparatory response. It is possible that because the valence rating task in the current studies does not require a quick reaction to the stimuli, it did not yield significant difference for reaction time and SPN. It is possible that an active and quick rating task might enhance anticipatory attention to emotional stimuli. In the absence of such a task, it failed to show differential anticipatory activity for emotional pictures (SPN). This explanation is supported by a number of previous studies, which found a robust SPN effect when the conditions involved a task relevant motor response (Kotani et al., 2003; Larbig et al., 1982; Ohgami et al., 2004; Poli et al., 2007; Wynn, Horan, Kring, Simons, & Green, 2010). All of these studies required motor responses to both negative and neutral pictures, the threat of unpleasant noise, painful shock stimuli, and punishment feedback and monetary reward based on task performance. These studies all found a robust SPN effect. These findings, therefore, suggest that during anticipation of salient stimuli, the impact of emotional stimuli on SPN reflect engagement of fundamental motivational systems (Bradley and Lang, 2007). In sum, it can be concluded that although high-arousal negative pictures sufficiently elicit differences in valence rating and relevant ERPs however, an active motor task similar to reward-punishment contingencies is needed to obtain a valence-specific SPN.

8.4.1.3 Scalp Topography

Qualitative differences in the scalp topography in all the three ERP studies were only observed during different latency periods during cue display. These topographic differences were elicited for laterality effects, but not for Anterior –posterior scalp sites. Most of the laterality effects were found for cue-related main effects and interaction only during cue display time specifically (200-800ms) at midline scalp site. This might represent spatial attention toward cues because cues were presented centrally. these findings are further supported by the findings of a study on spatial attention where cueing attention towards a location influenced memory processes (Leszczyński, Wykowska, Perez-Osorio, & Müller, 2013).

8.4.2 Neural activity following picture (Post-stimulus Dm-effect)

It was interesting to find out what happens to the neural activity after the picture display. In all three of the ERP studies of this project, data was recorded, investigated and analysed for picture-related Dm effect. The emotion enhancement memory effect was absent in previous studies that focused on examining Ps-Dm effect (Galli et al., 2014; Galli, Wolpe, et al., 2011). Findings obtained from the current ERP studies provided different findings. Dm effect was present regardless of the cue conditions: Informative or No-Cue, without topographical evidence. Similar trends were found in the study reported in chapter 6, where the amplitude for the remembered negative pictures was pronounced at right scalp side compared to neutral pictures.

As a reminder, the Ps-Dm effect was non-significant in these studies. However, this enhanced emotional memory effect was not present in the subsequent ERP study (chapter 7), which used all high-arousal negative pictures. An important point to be noted here is that Ps-Dm effect was obtained only in this study for the duration of the period when the cue was on the screen. However, Ps-Dm effect was not only significant under the informative cues but also for non-Informative cue conditions.

One possible explanation for the absence of Dm effect at the post-stimulus phase for informative cues was given in a study by Yick, Grüdtner Buratto, & Schaefer, (2015). The reason behind the absence of Dm effect at the post-stimulus phase might be due to pre-stimulus cues. Considering that the informative cues pushed the participants to anticipate the emotional valence of the upcoming stimuli, this anticipation might have had a preparatory effect that may have had a significant impact on memory encoding. This would, therefore, compete with the effects of memory on the encoding process. That is, the anticipation could have led to mental preparation, which may have then resulted in a less emotionally-arousing stimulus rating for the participant. If the participant is not emotionally aroused, then memory encoding would not be affected. However, this line of reasoning cannot account for the Ps-Dm effect for Non-Informative cues, where participants were not prepared for the upcoming stimuli.

8.5 Strengths of the experimental work

The key strengths of this experimental work lie in two things: one incorporating the anticipation related theoretical framework into the study of pre-stimulus effect and another refining the methodology to study this effect or phenomenon

8.5.1 Conceptual framework

i. The major contribution of this work is incorporating literature on cortical measures of anticipation into the study of Ps-Dm effect. Anticipation related ERP indices such as CNV and SPN, have largely been ignored in the studies which found Ps-Dm effect.

ii. Anticipation and preparation are two terms that have been used in an intertwined manner and done so without proper regard for their true definitions. In neuroscience, anticipation is distinguished from preparation (Perri et al., 2014). Anticipation is a perception-oriented stage of the expectancy process that involves passively waiting for the stimulus to appear. In contrast, preparation is a more motor-related stage that gets the motor system ready for the execution of a motor task (van Boxtel and Böcker,2004). In the available literature on the Pre-stimulus effect, a passive viewing of the pictures is involved without a motor task. The present set of studies also used the same paradigm. These studies claim that preparatory processes are responsible for memory formation at the anticipatory phase. Here, the question arises to which task participants were prepared for? If participants are prepared for viewing emotional pictures without any active action to respond to emotional stimuli, then they might have used implicit emotion regulation strategies during that anticipatory time period. This might be one mechanism working behind the non-significant Ps-Dm effect for informative cues compared to the non-informative cue condition. Mental preparation or motor preparation may be dissociable. In normal human adults, mental preparation reduces sensitivity towards upcoming emotional stimuli and is a significant marker of emotional well-being. A failure in preparation leads towards anxiety and other psychological problems.

iii. Another strength of this project is the addition of the memory factor in the anticipation-emotion relationship. The relationship between anticipation and memory has multiple aspects. There are two routes to study in determining the relationship between anticipation and emotion. One course addresses the processing stage from emotion to anticipation and the other from anticipation to emotion. In the current project, only the anticipation to emotion route was explored. The current research is a first step toward for a whole new avenue of research on anticipation and emotional memory

8.5.2 Refining of methodology

An important contribution of this project is to refine the methodology for the investigation of anticipation and emotional memory relationship. An initial attempt has been made by selecting all the parameters, keeping in mind the literature on cortical measures of anticipation. These parameters are cue types, time of cue presentation, cue-picture time intervals, ERP components related to anticipation. After setting these parameters, it is easy to replicate the findings and to remove inconsistencies in the use of methodology by those who are interested in it. Future studies might benefit it to facilitate replication and comparison of findings obtained across different laboratories.

8.6 Limitations and Study specific issues

Several limitations of this project need to be acknowledged. These limitations are specifically associated with restrictions due to the ERP technique.

8.6.1.1 Number of trials

The ERP technique relies on averaging to dissociate random noise from the underlying neural signal. The averaging is also necessary to obtain a sound signal to noise ratio. A maximum of 16 trials is required in experiments that do not use memory as a dependent measure. However, in the experiments that involve memory, such as this project, 12 artefact trials are acceptable because memory is a conservative measure of human behaviour. Further, the number of trials depends on the memory performance of the participants. Because of the lack of enough noise-free trials, there was a drop off of the data collected from the first two studies.

8.6.1.2 Functional inferences

Another major limitation of ERP methods is that inferences cannot always be drawn from the data. Many researchers use very specific ERP components, such as latency, scalp distribution, and duration. These components are considered markers of isolated cognitive processes though it is hard to understand the functional relationship between these markers and processes. Throughout this thesis, an explanation of main effects was offered based on the existing literature and the data provided in these studies.

Moreover, the components that have been investigated in this project, Ps-Dm effect, CNV and SPN in relation to emotional memory, are a relatively new avenue of research in cognitive neuroscience. The cognitive processes to which they are linked require more empirical evidence. Therefore, they are less established and less documented in the literature. The studies reported in this project have provided a starting point for developing a theoretical framework for an anticipatory model of emotional memory. Further research is required to test and replicate the findings that foreknowledge of the picture type is not necessary for Ps-Dm effect.

8.6.1.3 Methodological concerns

The present set of experiments has extended the findings of the current ERP literature on anticipation and emotional memory. Refining the methodology to investigate anticipation in relation to emotional memory is a particular strength of this research project. Instead of relying on the literature provided in few available studies on Ps-Dm effect, I have focused on the electrophysiological approach to study anticipation. However, many elements remained unexplored.

8.6.1.3.1 Cue stimuli (S1)

While reviewing the literature on anticipation, it was noticed that the electrophysiological literature and studies employ [S1-S2] paradigm to study cortical measures of anticipation. In this paradigm, S1 corresponds to the Cue stimuli. Type of cues is an important variable in ERP literature. Cues can be pictorial or non-pictorial or symbolic. The cues used in Galli, et al. study (2011) were pictorial in nature. Happy, sad and neutral cartoon faces (☺ ☹ 😐) were used to inform participants about the valence of upcoming positive, negative and neutral pictures. However, in most of the ERP studies that employed the S1-S2 paradigm, non-pictorial/symbolic cues have been used, such as upper case English letters, X, O, Z, etc. The reason might be that anticipation has a perceptual connotation and cues could help participants to form a mental representation of upcoming event: emotional or neutral (Bauch et al., 2014; Boxtel et al., 2004). In all the studies of this project, upper case letters were used as cues for two reasons: one, to avoid any confound associated with the use of discrete pictorial cues, and two, to allow the cue to be processed as a perceptual-cognitive activity and not as a mental image of cue, which is processed differently in the amygdala. How far different cue types influence anticipation related neural activity and Dm effect is beyond the objectives of this project. It is, therefore, a limitation of this study that a direct comparison of pictorial verse symbolic cues type could not be made to investigate its influence on the anticipated related neural activity. To the best of our knowledge, no study is available on this set of cue comparison in relation to anticipation and emotional memory. Future studies might focus on this factor as a variable.

8.6.1.3.2 Picture stimuli (S2)

Another important factor related to anticipation is the S2, i.e. picture stimuli. The properties of the S2 are anticipated in relation to the cues. The current project focused more on the manipulation of S2 but not S1 (the cue). In the first two ERP studies of this project, high and low arousal emotional pictures were selected as S2. The stimuli were contrasted as emotional vs. neutral without consideration that emotional stimuli can be differentiated on the basis of the emotional intensity (Buratto, Pottage, Brown, Morrison, & Schaefer, 2014). However, in the last ERP study only high arousal emotionally negative pictures were selected as S2. Manipulation of different intensity levels of negative pictures helped to investigate the key finding of the project. It implies that if to-be-anticipated stimuli are high in intensity, the mental representation of these stimuli is influenced strongly prior to its occurrence, and this influence might be observed at the anticipatory phase. One limitation of this project is that a comparison of high, low and medium intensity emotional pictures could not be made simultaneously in one single study.

8.6.1.3.3 Cue-picture time intervals

Cue-picture (S1-S2) time interval is an important factor because a negative slow wave, Contingent Negative Variation (CNV), develops during this time interval when that time interval is longer than 2 or more seconds (Poli et al., 2007; Van Boxtel & Brunia, 1994). CNV consists of at least two waves: early and late. Early waves are considered linked to the properties of the S1 and late waves to the S2. Late waves are named as Stimulus-Preceding Negativity and are associated with expectancy, motor preparation (Loveless & Sanford, 1974a,b) and emotional anticipation (Chwilla & Brunia, 1991). The cue-picture time interval in the current project was 3000ms, and this selection was made on the basis of a number of studies on anticipation (Poli et al., 2007; Walker, O'Connor, & Schaefer, 2011). Considering the presence of these early and late slow waves, current ERP data was broken down into two big time windows: ~0-1000ms for the study of early slow wave linked to cues, (S1) and 1000-3000ms for the study of late wave or SPN. In all the three current ERP studies, SPN a component for the anticipation of emotional valence was statistically non-significant. These findings cannot be interpreted, as the participants did not anticipate negative stimuli. These findings might be because the SPN is influenced by a shorter or longer S1-S2 time interval. Since this time interval was constant in all the studies, therefore, this factor cannot be ruled out. It is, therefore, difficult to make any conclusion regarding the relationship between anticipation of emotionally negative stimuli and SPN.

Further exploration of anticipatory S1-S2 paradigm via replication or control experiment would be a viable option for future research to further probe the relation between anticipation and emotional memory.

8.7 Future Directions

The field of emotional memory is relatively young, and studies regarding the role of anticipation in enhancing or impairing emotional memory are still in its infancy. However, there are a large number of compelling directions for future research. An initial attempt has been made through this project to remove the inconsistencies in the methodology and the processes associated with anticipation of emotional memories. However, this project is not the final word on this issue. Rather, it is just a beginning of a new research avenue.

Future research needs to examine more closely the links between anticipation, emotion and memory. A number of possible future studies using the same experimental setup can be designed. Slight differences can be made between the studies to fine-tune analysis, and drill down to any differences seen. Further, the effects already manipulated, including Ps-Dm, encoding, emotional valence, or ERP, can be further studied to determine causal relations between the components. Other changes made can include showing participants more emotionally salient images, and more acutely manipulating their emotional response to images, and then testing their memory encoding and anticipation. Since only females were used in these studies, it would be important to bring in male subjects, as well as other age groups, to better understand any effects.

Other sources of stimuli may be used, including video, which may be found to have a greater impact on emotional manipulation than static images would. Further, auditory stimuli may be used as well, to create a more emotional environment. Many individuals can be affected emotionally via music, and using that may be beneficial in these studies. Providing subjects with short stories that are emotionally salient may be another avenue of research that can be found to be worthwhile variations of the studies in this thesis.

One thing that was strongly felt during the project was that the anticipation in response to cues was not as strong as it should be. In other words, there is the possibility that the cue might not capture and maintain anticipatory attention, for the anticipation was not made by the participants themselves rather just in response to the cue presented to them. Future research on anticipation and emotion memory may focus on designing a paradigm in which prediction or anticipation is made by the participants themselves, without cues. This design might help in reducing the cognitive load of the perception of extra stimuli and cognitive processing such as working memory or discrimination processes. Moreover, this study design makes more sense as in the real life situation anticipation does not come with some discrete cues rather just as a perception of the situation.

This project has thrown up many questions that are in need of further investigation. For example, how do different cue types influence the brain waves related to emotion and memory? The findings of the current project revealed that valence and arousal of the to-be anticipated stimuli matters. However, it is unknown if the arousal and valence of the cue stimuli also produce some effects on memory.

How is the Contingent Negative Variation (CNV) influenced by different cue types: pictorial and verbal, and does it relates to memory and emotion in anyway? It may be determined that the cue type, beyond its emotional valence, does have an effect on memory encoding. Perhaps some individuals are more affected by visual cues, and others by verbal cues.

The relationship between the ERP component of the Stimulus-Preceding Negativity (SPN) and emotional anticipation and memory needs to also be further investigated. Does the SPN have a relationship to emotionally negative images if a quick response to pictures is required? What happens to the emotional memory when the cues are not congruent to the pictures anticipated? It could be that an individual may better remember incongruences because they do not match up with expectations. This would make sense as part of adaptability is recognizing how previous experience relates to current or future ones.

Research on anticipation and emotion memory should take into account the individual differences while exploring this issue, some of which are discussed below.

i. Tolerance of uncertainty is another variable that might affect the relation between emotion and memory, especially in those contexts where uncertainty is involved. For instance, if participants are expecting something under non-informative or temporally unpredictable anticipatory condition, the findings might be confounded by the individual difference in the tolerance of uncertainty.

ii. Individuals also differ in their use of emotion regulation strategies, which differently influence brain activity at the pre- and post-stimulus phases. Findings of the current research suggest that anticipation itself can be used as an emotional regulation strategy. This conclusion was made on the basis that, without explicit instruction, participants tend to respond less to emotionally negative stimuli. Individuals habitually and predominantly use one emotion regulation strategy greater than the other while dealing with the emotional stimuli. In the current investigation, no measure of emotion regulation was done by participants.

iii. However, a recent pupillary response study found a reappraisal strategy positively correlated with the high pupillary response at pre and post anticipatory phases compared to an expressive suppression strategy (Vandekerckhove et al., 2012). Future research may additionally measure the emotion regulation strategies used by participants to test the influence of anticipation and emotional memory formation. In one study, participants were asked to regulate their emotions in response to informative visual cues. Participants reduced negativity as a result of anticipation however in the current research and many others, with explicit instruction regarding regulation of emotion, individuals tend to down-regulate their emotion (Galli, Griffiths, & Otten, 2014). Further, it may be useful to produce an experimental design that compares implicit (without instruction) and explicit (specific instruction) emotion regulation strategies.

iv. Future research can be conducted to test the plausibility of whether anticipation can be learnt as a skill and if training in anticipatory skill can enhance our ability to detect negative emotions in others and to control our negative emotional state. A training program in anticipatory skill development might be used in some domains. The clinician and psychotherapist can use this skill training for therapeutic purposes while sports psychologist may use it to better help the athlete in cognitive control and emotion regulation during a tough situation.

8.8 Implications

Research into anticipation and its relationship to emotion and memory has several implications in the real world. From the biological perspective, emotions are psychological mechanisms that are evolved to solve adaptive problems, such as escaping from danger and predators, finding food, mates, shelter and protection, and being accepted and appreciated by other members of the species. Understanding of the underlying neurobiological routes and processes involved in forming emotional memories have been practically applied to understanding memory distribution in affective disorders of emotion. Specifically, research into emotion and memory has previously been applied to help develop therapeutic techniques to treat disorders of emotional memory such as phobias, and in treatment of post-traumatic stress disorder (PSTD). The studies presented in this project are important as they have added to the understanding of emotional memories and provided new knowledge that can be incorporated into, or used to guide future therapies for emotional disorders.

Anticipatory processes have been linked to the emotional disturbances in many psychiatric disorders, particularly the negative symptoms of anhedonia in schizophrenia patients, who show impairment in foresight in daily life (Eack & Keshavan, 2008). In laboratory settings, disturbances in anticipation have been correlated with reaction time and antisaccade and different anticipatory tasks (Avila et al., 2006; Fuller and Jahanshahi, 1999; Quintana et al., 2004). Further understanding of the scope and neural correlates of anticipatory behaviour and deficits may help explain several aspects of maladaptive functioning in schizophrenia. This understanding can be used to devise treatment plans and therapeutic interventions for these patients.

Few psychiatric disorders such as depression, anxiety and post-traumatic stress disorder exhibit a severe impairment in memory and emotion regulation. An understanding of the interaction between anticipation and emotion may help in enhancing the use of emotion regulation strategies. Anticipatory brain activity influences the encoding of emotional events, and this activity can be modulated by regulation of emotions (Galli, Griffiths, & Otten, 2012). Participants use different emotion regulation strategies such as reappraisal, avoidance and detachment, etc. In everyday life or in a lab setting, regulation of emotion before the occurrence of an aversive event might help reduce the impact of the negative event on memory.

Understanding of the anticipatory system may help in developing brain-computer interfaces (BCI). Anticipatory behaviour is, by definition, the prediction of future events and the value those events have on the current behaviour of an individual. Therefore, developing a computer system that utilizes algorithms that relate to anticipated behaviours may be beneficial in helping to better design robots used by those with lost or paralyzed limbs. Anticipation is expressed through consequences. Further work on anticipation might help devising a model of agent-environment interactions in which anticipation-related brain waves can be used to control devices such as a robot (Bozinovski & Bozinovska, 2004).

8.9 Concluding remarks

The greatest motivation for this thesis came from the theory, predicated on changes observed in pre-stimulus ERP activity, that anticipation leads to preparation, which increases processing efficiency- which in turn facilitates memory encoding (Park and Rugg 2010; Galli, Wolpe et al. 2011). In contrast, data from another study revealed that this pre-stimulus Dm effect can also be observed where no opportunity for preparation exists (Yick, Buratto & Schaefer, 2015). This led us to predict that memory related ERPs at the anticipatory phase might reflect the random fluctuation in attention rather than preparatory activity. By this experimental research, it is concluded that the pre-stimulus effect is not specific to informative cues only. Rather it can be elicited when participants have no precise information about the valence of upcoming emotionally negative stimuli. It is also concluded that Ps-Dm effect is more likely to be elicited in the earlier time window while the cue is present on the screen, which implies that Ps-Dm effect is likely to be sensitive to the presence of cue display duration. The findings provide no evidence for this effect in the time window when the cue disappears from the screen. It suggests that anticipatory attention and activity diminishes when the cue disappears. The findings also highlight that Ps-Dm effect is strongly elicited when the arousal level of the anticipated negative stimuli is high as compared to low-arousal stimuli, and provide support for the modulation model of EEM. All these conclusions have been made with extreme caution as for some of the conclusions strong evidence is available in the literature, while some other are novel findings that highlight the need for further research. Future directions and implications for the current research project are discussed.

Appendices

Appendix A

Consent Form for the Experiment 1 &2 reported in Chapter 3

Durham University – Department of Psychology

CONSENT FORM

TITLE OF PROJECT:

Role of level of processing in emotional memory enhancement

Please cross out as necessary

1. Have you read the Instruction sheet? YES / NO

2. Do you understand that some of the words you will read in this study are emotional in nature such as rape, suicide and suffocation? YES / NO

3. Have you been shown examples of these words prior to consenting? YES / NO

4. Have you had an opportunity to ask questions and to discuss the study? YES / NO

5. Have you received satisfactory answers to all of your questions? YES / NO

6. Have you received enough information about the intended uses of, and access arrangements to, any data which you supply? YES / NO

7. Were you given enough time to consider whether you want to participate? YES / NO

8. Do you understand that you are free to withdraw from the study:
   - at any time
   - without having to give a reason for withdrawing
   - without any adverse result of any kind. YES / NO

9. Do you consent to participate in the study? YES / NO

Signed (Participant).. **Date** ....

Name (IN BLOCK LETTERS) ....

Signed (Person obtaining consent) .... **Date** ....

Name (IN BLOCK LETTERS): NAZOOL-E-TABASSUM

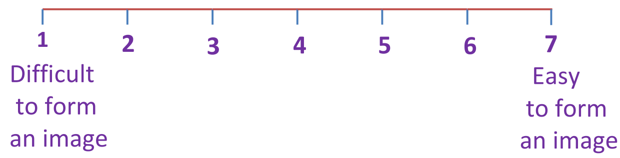
Appendix B

Study 1a-Participation Information Sheet for Rating Survey

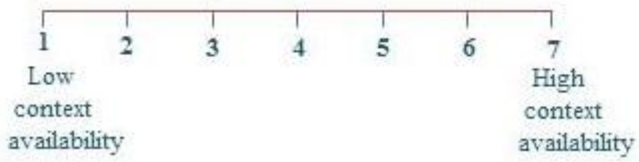
This rating study is part of an experiment which intends to investigate the effect of emotion on memory. However, the purpose of this rating survey is to get rating on those three dimensions of words which might interact with the independent variable of the main study. The required task is quite simple and straight forward in this survey that is rating each word on a given dimension, say, Concreteness/ Abstract, Image-ability, or Context Availability on a seven-point scale given below.

1. Abstract/Concrete Dimension

2. Image-ability Dimension



3. Context Availability Dimension



You have to rate only one of the three dimension of the words and its dependent upon the accreditation of researcher. Example for the emotional word is rape, skull, death, etc. Please do not hesitate to contact researcher to discuss any questions you have related to this survey. I will try to give satisfactory answers to all of your queries before your participation. It is an online study, the link for which will be sent to you via mail on your willingness to participate in the study. However, you may withdraw at any time without any penalty.

If you have no questions and willing to participate in this survey, please contact Nazool-e Tabassum at nazool.tabassum@durham.ac.uk for consent form and Survey link.

Appendix C

Revised list of all words selected from ANEW and matched on Linguistic characteristics

Negative words (n = 120)			Neutral words (n = 120)		
abduction	gloom	scar	absurd	golfer	quality
abortion	gossip	scream	activate	grass	rattle
abuse	greed	scum	adult	habit	reptile
addict	grenade	scurvy	alert	hamburger	reserved
agony	grief	shark	alien	heroin	reunion
allergy	grip	sickness	alley	highway	revolt
ambulance	headache	slap	autumn	hydrant	runner
anger	hooker	slaughter	avenue	icebox	saint
assassin	horror	slave	bake	idol	salad
assault	hostage	slum	banner	industry	salute
avalanche	hurricane	smallpox	barrel	insolent	sentiment
bees	infection	snake	beast	invest	shadow
bored	injury	spanking	blond	iron	shelter
burial	intruder	spider	bowl	jelly	sphere
cancer	lawsuit	starve	boxer	journal	spray
cane	loser	stink	cabinet	kerosene	swamp
carcass	louse	stress	cannon	ketchup	taxi
cemetery	madman	suffocate	cellar	knot	tease
cockroach	maggot	syphilis	chaos	lamb	tennis
coffin	malaria	terrorist	circle	legend	theory
corpse	maniac	thief	cloud	lighthouse	tool
coward	massacre	tobacco	coast	locker	tower
crash	mold	tomb	coin	lump	trunk
crush	morgue	toothache	column	manner	vampire
crutch	mosquito	torture	contents	material	vanity
dagger	murderer	trash	context	metal	vehicle
debt	mutation	trauma	cord	method	vest
deformed	needle	urine	corridor	moral	virgin
delay	nightmare	vomit	cottage	museum	virtue
depressed	outrage	wasp	custom	mystic	voyage
disaster	panic	whore	dawn	neurotic	whistle
discomfort	paralysis	wounds	dentist	nonsense	writer
distress	pervert	**Words used**	detail	nursery	**Words used**
dummy	pinch	**as Primacy**	dirt	option	**as Primacy**
dump	poison	**& Recency**	diver	overwhelm	**& Recency**
execution	poverty	nuisance	employment	pamphlet	windmill
fatigue	prick	humiliate	event	passage	umbrella
fever	punishment	crisis	fabric	patent	lion
filth	quarrel	menace	flag	plain	razor
flood	rape	reject	foam	poetry	cliff
foul	ridicule	rage	fragrance	poster	violin
fraud	riot	detest	garment	prairie	basket
garbage	robber	inferior	garter	priest	butter
germ	scapegoat		gender	privacy	

<u>Appendix D</u>

Participant Information Sheet - Experiment 1&2 (Chapter 3)

The purpose of this information sheet is to introduce you to the objectives of the current study and provide you with an opportunity to ask questions before you begin.

The main experiment consists of reading a series of words on a computer screen according to the instruction given in the experiment and recalling them subsequently. You should also be aware that some of the words have a negative connotation. If you generally feel distressed while reading such words (for example rape, suffocation and death), then you may not wish to participate. The experiment will last around one hour, and you will be paid £6 or course credits. The study will take place at Wolfson Research Institute, Queen's Campus. The only condition is right-handedness and to be a native speaker of English language.

Please do not hesitate to contact me to discuss any questions that you have related to this survey before participation. I will try to give satisfactory answers to all of your queries before you agree to participate. You have enough time to consider whether you want to participate. You may withdraw at any time without any penalty.

Please contact me at nazool.tabassum@durham.ac.uk

Researcher,
Nazool-e-Tabassum
Ph.D. Student,
Cognitive Neuroscience Research Unit
Wolfson Research Institute (G009)
Durham University, Queen's Campus
Stockton- on-Tees. TS17 6BH
0191 33 40588

Appendix E

Instructions sheet for Shallow encoding condition

The experiment will be conducted in the lab, sitting in front of a computer screen.

What will you see?

You will see a list of words on the computer screen one by one.

Fixation

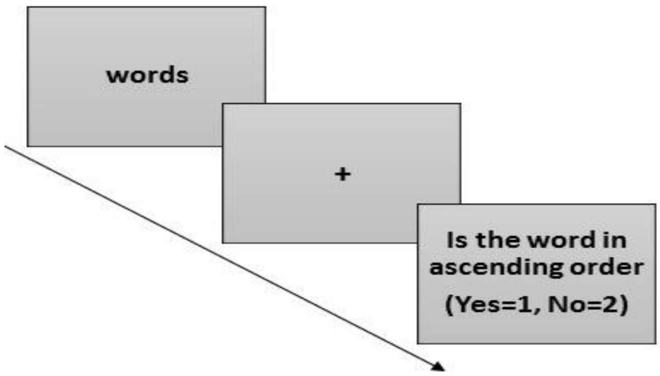
A fixation (+) point would appear after each word in the centre of the screen. You need to fixate at it until the word slide appears.

Task

The task is to find an alphabetical relation between the first and last letter of each word. The relation will be in ascending if the first and last letter is in alphabetical order A-Z such as ‘clear’ because “C” becomes before “R” alphabetically. The relation will be descending if they are in reverse order Z-A such as ‘hope’ because “H” comes after “E” alphabetically. So you are supposed to answer “Is the word ascending”? Just to clarify, it means if the relation between first and last letter in alphabetical order or not? You will press button 1 on the response box for ‘Yes’ and 2 for ‘No’.

Note: If you come across a word which starts and ends with the same letter (e.g. status) then consider it in descending order, not in ascending order (it is specific to this experiment).

Process: One trial



Process: Whole experiment

The experiment will run 8 lists of words (30 words in each list). After each list (30 words), you will do some solved **mathematics** equations. **Then,** you will be given 4 minutes to **recall** as many words as you can on a ‘Recall Sheet’ provided for this purpose. It is important that you report every word that you can remember. Try not to leave out any word even if you start to feel that you are guessing. If you do feel it is a guess, please report this on the sheet.

Please do not hesitate to ask any questions regarding instructions and participation.

Appendix F

Instructions sheet for Semantic encoding condition

The experiment will be conducted in the lab, sitting in front of a computer screen.

What will you see?

You will see a list of words on the computer screen one by one.

Fixation

A fixation (+) point would appear after each word in the centre of the screen. You need to fixate on it until the task slide appears.

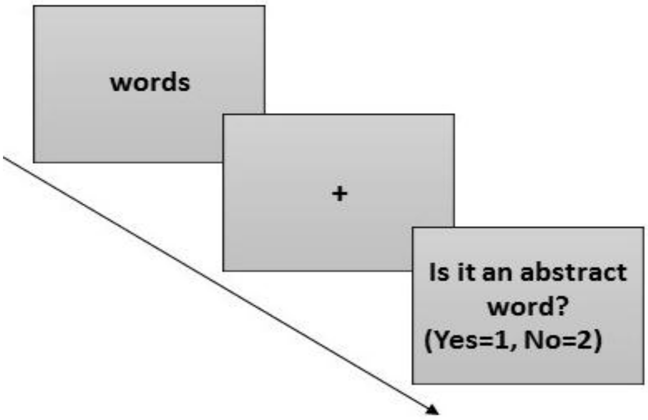
Task

For each word, focusing the meaning of the words, your task is to tell whether the word is abstract or not.For your understanding, **abstract words** are defined as something considered apart from some material basis or object such as word “intelligence” or “soul” etc. Abstract words contrast with **concrete words** which denote something material and represent an actual substance or thing such as table or mug etc.

Response

In response to the question, “Is it an abstract word?” You are requested to press 1 for ‘Yes’ and 2 for ‘No’.

Process: One trial



Process: Whole Experiment

After List 1 (30 words) you will do some solved **mathematics** equations.

After you will be given 5 minutes to **recall** as many words as you canon a ‘Recall Sheet’ provided for this purpose. It is important that you report every word that you can remember. Try not to leave out any word even if you start to feel that you are guessing. If you do feel it is a guess, please report this on the sheet.

In this way, you will go through 8 lists of words.

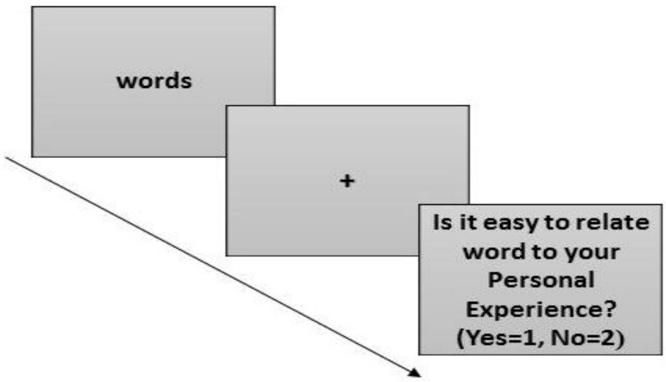
Please do not hesitate to ask any questions regarding instructions and participation.

Appendix G

Instructions sheet for Self-Referential encoding condition

The experiment will be conducted in the lab, sitting in front of a computer screen.
What will you see?
You will see a list of words on the computer screen one by one.
Fixation
A fixation (+) point would appear after each word in the centre of the screen. You need to fixate on it until the task slide appears.
Task
You will see a list of words. Please bring to mind an important personal experience involving each of the words presented. For each word you will be asked if it was easy to bring an experience to mind. For Instance, the word 'sad' or 'despair' may remind you the times when you felt sadness or despair due to some person, situation or thing, therefore, in one or the other way it may relate to your personal experience. Similarly, the word 'doll' or "care" may be a reminder of some important personal experience in past. For some items it may be very likely you were able to bring an experience to mind. For others, it may be unlikely. It is up to you to decide.
Response
In response to the question, "Is it easy to relate to your PE?" (PE= Personal Experience)**.** You are requested to press 1 for 'Yes' and 2 for 'No'.

Process: One trial



Process: Whole Experiment
After List 1 (30 words) you will do some solved **mathematics** equations.
After you will be given 4 minutes to **recall** as many words as you canon a 'Recall Sheet' provided for this purpose. It is important that you report every word that you can remember. Try not to leave out any word even if you start to feel that you are guessing. If you do feel it is a guess, please report this on the sheet.
In this way, you will go through 8 lists of words.
Please do not hesitate to ask any questions regarding instructions and participation.

Thank you very much

Appendix H

List of IAPS pictures used in the Studies reported in 4, 5, 6 chapters

Legend
Picture: IAPS (International Affective Picture System) identification number
Valence: 1 = negative … 3 = neutral … 5 = positive
Arousal: 1 = low … 5 = high

Picture	Valence	Arousal
10.bmp	1.72	3.83
11.bmp	2.11	2.94
1111.bmp	2.39	3.44
1120.bmp	2.63	3.05
1121.bmp	3.68	2.18
1200.bmp	2.50	2.86
121.bmp	1.72	3.94
1220.bmp	2.44	3.11
1270.bmp	2.11	2.78
1274.bmp	2.23	2.73
128.bmp	1.61	3.78
1280.bmp	2.27	2.86
129.bmp	1.39	4.11
130.bmp	2.00	3.67
1300.bmp	2.27	3.05
1301.bmp	2.27	2.91
1313.bmp	3.32	2.41
132.bmp	2.06	3.33
1321.bmp	3.11	2.78
1390.bmp	2.89	2.89
1616.bmp	2.89	2.72
18.bmp	1.45	3.73
1930.bmp	2.39	3.33
1931.bmp	2.91	3.14
1935.bmp	2.56	2.89
1945.bmp	2.67	3.00
1947.bmp	3.67	2.72
2025.bmp	3.56	2.39
2053.bmp	1.91	3.50
2055.1.bmp	2.32	3.14
2095.bmp	1.45	3.68
2100.bmp	2.39	2.72
2120.bmp	2.11	3.11
2141.bmp	2.05	3.05
2191.bmp	3.67	2.06
2200.bmp	3.00	2.22
2205.bmp	1.67	3.33
2206.bmp	2.67	2.06
2235.bmp	3.71	2.11
2272.bmp	3.00	2.44
2276.bmp	1.83	2.78
2278.bmp	2.44	2.94

Picture	Valence	Arousal
5455.bmp	3.28	2.61
5500.bmp	3.11	1.94
5535.bmp	3.17	2.11
57.bmp	2.00	3.05
5740.bmp	3.72	1.94
58.bmp	1.94	3.28
5900.bmp	3.72	2.28
5972.bmp	2.77	2.59
6000.bmp	2.83	2.83
6010.bmp	2.41	2.68
6020.bmp	1.67	3.22
6150.bmp	3.11	1.67
6200.bmp	2.45	2.77
6210.bmp	2.36	2.45
6212.bmp	1.89	3.67
6242.bmp	2.23	2.95
6244.bmp	2.32	3.05
6313.bmp	2.11	3.00
6360.bmp	1.95	3.14
6370.bmp	1.94	3.17
6415.bmp	1.55	3.86
6510.bmp	2.00	3.32
6555.bmp	1.86	3.43
6570.2.bmp	3.00	2.61
6570.bmp	1.95	3.05
6571.bmp	1.89	3.39
6821.bmp	1.82	3.05
6830.bmp	2.09	2.91
6831.bmp	1.78	3.44
6834.bmp	2.32	2.91
6838.bmp	1.95	3.27
6840.bmp	2.06	3.06
6940.bmp	2.32	3.09
7000.bmp	3.11	1.89
7002.bmp	3.33	1.67
7004.bmp	3.28	1.72
7006.bmp	3.17	1.67
7009.bmp	3.39	1.56
7010.bmp	3.22	1.83
7020.bmp	2.94	1.89
7025.bmp	3.00	1.61
7030.bmp	2.83	1.89

2280.bmp	3.17	2.39
2312.bmp	2.77	2.43
2352.2.bmp	1.55	3.95
2357.bmp	3.28	2.28
2372.bmp	3.39	2.33
2375.1.bmp	2.00	3.05
2381.bmp	3.28	2.33
2383.bmp	3.17	1.89
2385.bmp	3.28	2.28
2393.bmp	3.22	2.06
2394.bmp	3.06	2.11
2399.bmp	2.41	2.36
2410.bmp	2.89	2.67
2435.bmp	3.67	2.11
2440.bmp	3.17	1.89
2441.bmp	2.50	2.89
2455.bmp	2.50	2.45
2480.bmp	2.89	2.06
2485.bmp	3.33	2.44
2487.bmp	3.72	2.50
2490.bmp	2.41	2.50
2491.bmp	2.72	2.50
2495.bmp	2.89	2.22
2499.bmp	3.56	2.44
2514.bmp	3.28	2.28
2516.bmp	3.39	2.17
2518.bmp	3.78	2.17
2570.bmp	3.11	2.28
2575.bmp	3.28	2.50
2579.bmp	3.67	2.22
2580.bmp	3.50	2.11
2590.bmp	2.71	2.36
2595.bmp	3.45	2.11
2600.bmp	3.22	2.22
2616.bmp	3.39	2.67
2620.bmp	3.78	2.39
2635.bmp	3.56	2.33
2682.bmp	2.36	2.68
2683.bmp	1.86	3.24
2688.bmp	1.72	3.50
2692.bmp	2.32	2.73
2694.bmp	2.22	3.00
2700.bmp	2.17	2.56
2710.bmp	1.86	3.09
2715.bmp	2.64	2.50
2722.bmp	2.67	2.28
2730.bmp	1.68	3.68
2745.1.bmp	3.00	2.06
2745.2.bmp	2.56	2.67
2749.bmp	3.22	2.00
2750.bmp	2.00	2.86
2751.bmp	2.11	3.22
2753.bmp	2.45	2.50
7031.bmp	2.89	1.78
7034.bmp	2.72	2.18
7035.bmp	3.39	1.94
7036.bmp	3.28	2.11
7037.bmp	3.11	2.28
7038.bmp	3.17	1.89
7039.bmp	3.61	2.22
7040.bmp	2.72	1.94
7041.bmp	3.56	1.78
7050.bmp	3.06	1.94
7060.bmp	2.89	1.89
7080.bmp	3.00	1.78
7175.bmp	3.28	1.78
7211.bmp	3.33	1.78
7217.bmp	3.11	1.67
7359.bmp	2.27	2.91
7361.bmp	2.17	3.44
7493.bmp	3.44	2.18
7496.bmp	3.06	2.56
7503.bmp	3.28	2.33
7550.bmp	3.06	1.83
7620.bmp	3.61	2.53
7700.bmp	2.72	2.28
7705.bmp	3.00	1.78
7710.bmp	3.50	2.00
7820.bmp	3.22	2.11
7830.bmp	3.11	2.39
7950.bmp	3.33	1.56
8.bmp	2.11	2.83
8010.bmp	2.83	2.67
8231.bmp	2.50	2.91
8311.bmp	3.61	2.33
8465.bmp	3.83	2.39
8480.bmp	2.41	3.41
9000.bmp	2.27	2.45
9001.bmp	2.61	2.50
9005.bmp	2.28	3.11
9006.bmp	1.82	3.05
9007.bmp	1.72	3.11
9008.bmp	2.09	3.09
9010.bmp	2.50	2.45
9040.bmp	1.28	4.00
9041.bmp	2.00	3.17
9042.bmp	1.68	4.05
9045.bmp	2.67	3.17
9046.bmp	2.27	2.72
9090.bmp	2.50	2.27
9101.bmp	2.59	2.36
9110.bmp	2.68	2.32
9180.bmp	2.00	3.22
9181.bmp	1.55	3.63
9190.bmp	2.73	2.45
9210.bmp	3.11	2.06

2795.bmp	2.44	2.94
28.bmp	1.67	3.44
2800.bmp	1.44	2.89
2830.bmp	3.11	2.78
2840.bmp	3.28	2.39
2850.bmp	3.17	2.61
2870.bmp	3.56	2.22
2880.bmp	3.11	2.00
2900.bmp	2.11	2.76
2981.bmp	1.78	3.67
3000.bmp	1.23	4.36
3005.1.bmp	1.27	3.95
3015.bmp	1.28	4.22
3022.bmp	2.44	3.22
3053.bmp	1.14	4.27
3061.bmp	1.36	4.05
3063.bmp	1.11	4.61
3064.bmp	1.28	4.33
3068.bmp	1.36	4.09
3069.bmp	1.18	4.27
3071.bmp	1.45	3.73
3080.bmp	1.36	3.86
3101.bmp	1.61	3.78
3102.bmp	1.22	4.11
3150.bmp	1.39	4.39
3160.bmp	1.95	3.36
3168.bmp	1.22	4.50
3170.bmp	1.36	4.18
3181.bmp	1.72	3.39
32.bmp	1.86	3.41
3220.bmp	1.94	3.33
3230.bmp	1.86	3.18
3250.bmp	1.64	3.82
3261.bmp	1.45	3.86
3266.bmp	1.23	4.45
3280.bmp	2.59	2.50
3300.bmp	1.94	3.00
3301.bmp	1.56	3.56
3350.bmp	1.64	3.59
3400.bmp	1.36	4.14
35.bmp	1.64	3.36
3500.bmp	1.86	3.14
3530.bmp	1.77	3.50
3550.bmp	2.06	3.39
4571.bmp	3.61	2.28
4605.bmp	3.33	2.22
4621.bmp	2.23	2.86
4635.bmp	2.09	3.41
4664.2.bmp	1.73	3.77
5120.bmp	2.78	2.47
5130.bmp	2.61	2.33
5390.bmp	4.06	1.94
5395.bmp	3.18	2.28
9220.bmp	2.14	2.27
9250.bmp	2.06	3.17
9252.bmp	1.44	3.89
9253.bmp	1.28	4.11
9265.bmp	1.59	3.27
9270.bmp	2.41	2.64
9290.bmp	2.19	2.59
9301.bmp	1.55	3.64
9330.bmp	2.18	2.73
9331.bmp	2.78	1.89
9340.bmp	2.06	2.89
9360.bmp	2.67	2.33
9373.bmp	2.06	3.39
9390.bmp	2.32	2.33
9404.bmp	2.22	3.06
9405.bmp	1.45	3.95
9409.bmp	2.22	3.00
9410.bmp	1.23	4.14
9415.bmp	2.14	2.68
9417.bmp	2.86	2.36
9420.bmp	1.45	3.82
9421.bmp	1.89	3.06
9430.bmp	1.91	3.23
9432.bmp	1.95	3.23
9433.bmp	1.50	3.83
9435.bmp	2.00	3.14
9440.bmp	2.00	3.44
9452.bmp	2.22	3.44
9470.bmp	2.17	3.39
9471.bmp	2.28	2.61
9480.bmp	1.89	3.11
9490.bmp	1.72	4.06
9495.bmp	2.56	3.39
95.bmp	1.78	3.61
9500.bmp	1.68	3.36
9520.bmp	2.50	3.00
9530.bmp	1.89	3.17
9560.bmp	1.94	3.00
9561.bmp	1.50	3.36
9570.bmp	1.64	3.73
9571.bmp	1.94	3.06
9592.bmp	2.27	3.14
9594.bmp	2.33	2.94
9600.bmp	2.05	3.09
9620.bmp	2.27	3.05
9622.bmp	1.91	3.00
9630.bmp	2.45	2.82
9800.bmp	2.09	2.91
9810.bmp	1.91	3.27
9830.bmp	1.83	2.72
9910.bmp	2.05	3.18
9912.bmp	2.22	2.94
9921.bmp	1.82	3.68

Appendix I

Participant Information sheet

The purpose of this "Information sheet" is to introduce you to the objectives of the current study and to provide you with an opportunity to ask questions before you consent to take part.

What the experiment is about?

This is an electroencephalogram (EEG) experiment, in which we record electrical activity produced by the brain with the help of small electrodes which are placed on the scalp of your head. In this experiment, you will be shown a series of pictures on a computer screen while your brain activity is recorded. Before each picture is displayed, you will see a cue symbol which will inform you whether the upcoming picture is neutral or negatively charged so that you can get ready for viewing it. After you see each picture, you will be asked to rate how the picture made you feel on a negative-to-positive scale by pressing a button (1–5).

We are looking for right-handed female participants who have not previously taken part in an experiment with emotional stimuli.

You should be aware that some of the pictures are very negative. A sample of the types of emotional pictures that will be used in the experiment is given on the next page. If you generally feel distressed while looking at these pictures, then we advise you not to participate.

The experiment will be carried out over two consecutive days (90-min session on the first day, 60-min session on the second day). It is crucial that you attend both sessions.

On the completion of the whole experiment, you will be paid £ 25 in cash or the equivalent in course credits (2.5 hours).

Screening phase

Before you can take part in the experiment, you will fill out three online questionnaires. The questionnaires inquire about your mood, medical history and suitability for an EEG study. The whole task takes approximately 15 minutes. You will not be paid for this stage.

If you are willing to take part, please let us know. We will send you a web link to access the online questionnaires and an ID number to be able to complete the questionnaires.

After completing the questionnaires, we will assess them and will let you know if you are eligible to take part in the study. If eligible, we will contact you to book the sessions.

It is agreed that the data collected during the experiment will be used for the purpose of my Ph.D. thesis, including subsequent potential journal articles. In addition, the raw data will be stored for at least 10 years. It is important for you to know that the data collected during the experiment will be held anonymously, meaning that it will not be possible to trace the data back to you. However, you may access the results of this experiment by signing a "Result Information Request Form" at the time of your participation in the experiment.

Please do not hesitate to contact us (nazool.tabassum@durham.ac.uk) to discuss any questions that you may have related to this experiment. You may withdraw from this study at any time.

Examples of emotionally negative images to be used in the experiment
(These pictures will be shown to participants before consenting to participate)

Here are selections of the type of the pictures that will be presented to you during the experiment. Some of the images will be neutral, and some will be emotional (negatively charged).

Please look at the pictures below.

If you feel you would be uncomfortable viewing these sorts of images during the experiment, you are free to stop the experiment at this stage or later at any other time without any penalty.

Best Regards,
Nazool-e-Tabassum
Ph.D. Student,
Cognitive Neuroscience Research Unit
Wolfson Research Institute (G009) Queen's Campus

Appendix J

Consent Form used in all the studies reported in chapters 4 -7

Durham University – Department of Psychology

TITLE OF PROJECT:

Role of anticipation in emotional memory enhancement

Please cross out as necessary

Have you read the Instruction sheet? YES / NO

Do you understand that some of the pictures you will see in this study are emotional in nature? YES / NO

Have you been shown examples of these pictures prior to consenting? YES / NO

Have you had an opportunity to ask questions and to discuss the study? YES / NO

Have you received satisfactory answers to all of your questions? YES / NO

Have you received enough information about the intended uses of, and access arrangements to any data which you supply? YES / NO

Were you given enough time to consider whether you want to participate? YES / NO

Do you understand that you are free to withdraw from the study:

- at any time
- without having to give a reason for withdrawing
- without any adverse result of any kind. YES / NO

Do you consent to participate in the study? YES / NO

Signed (Participant)..**Date** ....
Name (IN BLOCK LETTERS)...
Signed (Person obtaining consent) .... **Date**................. ...
Name (IN BLOCK LETTERS): NAZOOL-E-TABASSUM

Appendix K

Depression Anxiety and Stress scale (DASS)

Screening was conducted through an online questionnaire, accessible to participants only after they have expressed their initial interest in taking part the experiment

DASS *Name:* *Date:*

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you *over the past week*. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

1	I found myself getting upset by quite trivial things	0	1	2	3
2	I was aware of dryness of my mouth	0	1	2	3
3	I couldn't seem to experience any positive feeling at all	0	1	2	3
4	I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5	I just couldn't seem to get going	0	1	2	3
6	I tended to over-react to situations	0	1	2	3
7	I had a feeling of shakiness (e.g.,, legs going to give way)	0	1	2	3
8	I found it difficult to relax	0	1	2	3
9	I found myself in situations that made me so anxious I was most relieved when they ended	0	1	2	3
10	I felt that I had nothing to look forward to	0	1	2	3
11	I found myself getting upset rather easily	0	1	2	3
12	I felt that I was using a lot of nervous energy	0	1	2	3
13	I felt sad and depressed	0	1	2	3
14	I found myself getting impatient when I was delayed in any way (eg, lifts, traffic lights, being kept waiting)	0	1	2	3
15	I had a feeling of faintness	0	1	2	3
16	I felt that I had lost interest in just about everything	0	1	2	3
17	I felt I wasn't worth much as a person	0	1	2	3
18	I felt that I was rather touchy	0	1	2	3

19	I perspired noticeably (eg, hands sweaty) in the absence of high temperatures or physical exertion	0	1	2	3
20	I felt scared without any good reason	0	1	2	3
21	I felt that life wasn't worthwhile	0	1	2	3

22	I found it hard to wind down	0	1	2	3
23	I had difficulty in swallowing	0	1	2	3
24	I couldn't seem to get any enjoyment out of the things I did	0	1	2	3
25	I was aware of the action of my heart in the absence of physical exertion (e.g.,, sense of heart rate increase, heart missing a beat)	0	1	2	3
26	I felt down-hearted and blue	0	1	2	3
27	I found that I was very irritable	0	1	2	3
28	I felt I was close to panic	0	1	2	3
29	I found it hard to calm down after something upset me	0	1	2	3
30	I feared that I would be "thrown" by some trivial but unfamiliar task	0	1	2	3
31	I was unable to become enthusiastic about anything	0	1	2	3
32	I found it difficult to tolerate interruptions to what I was doing	0	1	2	3
33	I was in a state of nervous tension	0	1	2	3
34	I felt I was pretty worthless	0	1	2	3
35	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
36	I felt terrified	0	1	2	3
37	I could see nothing in the future to be hopeful about	0	1	2	3
38	I felt that life was meaningless	0	1	2	3
39	I found myself getting agitated	0	1	2	3
40	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
41	I experienced trembling (e.g, in the hands)	0	1	2	3
42	I found it difficult to work up the initiative to do things	0	1	2	3

Appendix L

EEG Screening Form

Please complete the following questions for screening purposes. We are bound by the British Psychological Society to keep your responses confidential, and your identity will not be disclosed in any circumstances.

1. Gender: Male ☐ Female:☐

2. Age (please write your age): ________________ years

3. Are you right-handed ☐ left-handed?☐

5. Have you ever had a brain surgery?
Yes ☐ no ☐

6. Have you ever had a severe brain injury that required hospital treatment?
Yes ☐ no ☐

7. Are you currently taking any neurological/psychotropic medication such as:
-Anticonvulsants/antiepileptics
- Antidepressants
- Tranquillizers
- Neuroleptics
- Antipsychotic
Yes ☐ no ☐
(please answer yes if you are taking any of these or any neurological/psychoactive medication that is not included in the list)
8. To the best of your knowledge, have you ever suffered from any form of brain/neurological condition?
Yes ☐ no ☐
9. To the best of your knowledge, do you suffer from any skin condition?
Yes ☐ no ☐
10. Do you have wounds in your scalp?
Yes ☐ no ☐
11. Do you regularly take recreational drugs (other than alcohol and tobacco)?
Never ☐ rarely ☐ sometimes ☐ frequently ☐ every day ☐
12. Do you regularly smoke tobacco?
Never ☐ rarely ☐ sometimes ☐ frequently ☐ every day ☐
13. Do you regularly drink alcohol?
Never ☐ rarely ☐ sometimes ☐ frequently ☐ every day ☐

Participant	**Person approving EEG Screening Form**
Print Name :--------------------------------	Print Name ----------------------------------
Signature : --------------------------------	Signature -----------------------------------
Date :--	Date : --------------------------------------

Appendix M

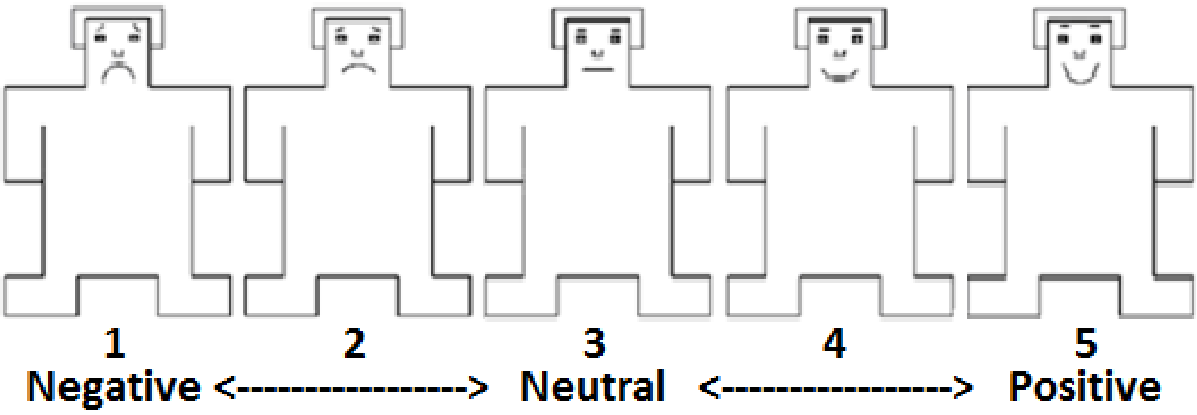
Instructions Sheets (Study Phase)

1. You will see a series of neutral or negative pictures. Before each picture, a letter will be presented to indicate whether the upcoming picture is neutral or negative.
   - "O" indicates that the pictures are going to be neutral
   - "X" indicates that the picture is going to be negative
   - "Z" indicates that the picture can be either neutral or negative
   -

2. Whenever possible, use these letter cues to help you to get ready for seeing the picture.

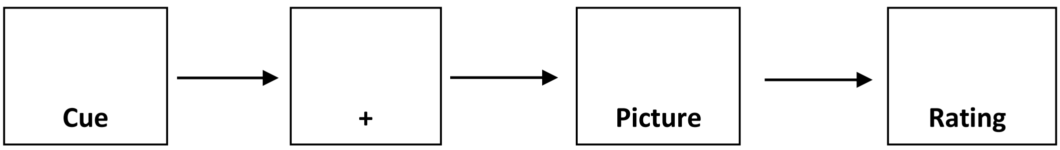
3. Refrain from blinking when looking at the letters or pictures. You may blink when the plus sign **(+)** is on the screen.

4. After seeing each picture, rate how the picture made you feel (for example, did it elicit negative feelings, positive feelings or no feelings at all?). To enter your rating, press buttons 1 to 5 following the scale below. Please make use of the full range of the scale.



5. This positive/negative scale ranges from a frown to a smile:
   - If the image you saw made you feel unhappy, disgusted, or upset, enter 1 or 2.
   - If the image you saw made you feel happy, pleased, or content, enter 4 or 5.
   - If the image you saw made you feel neither pleased nor upset (neutral), enter 3

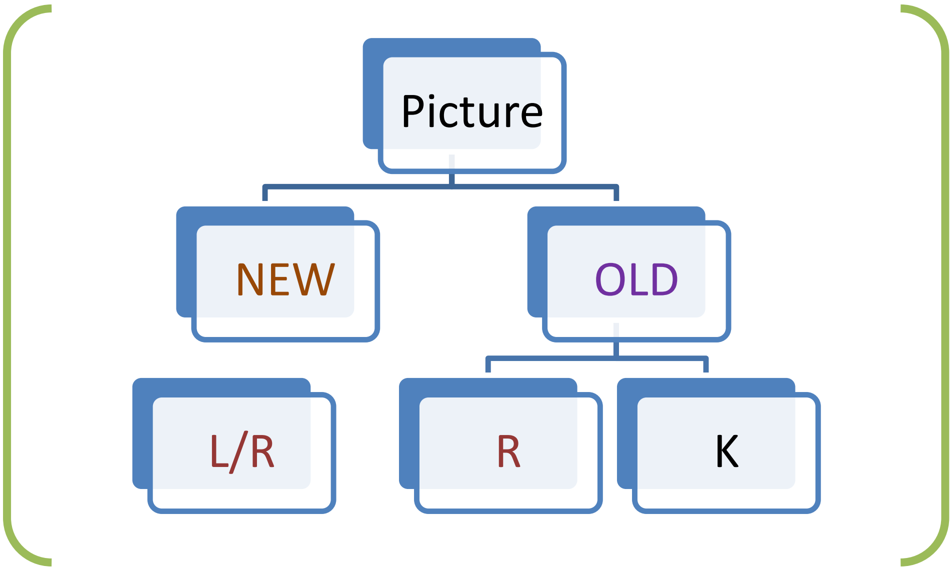
6. The figure below illustrates a study trial.



Appendix N

Instructions Sheets (Memory Test Phase)

Please read the following instructions carefully. In this phase of the experiment, your memory will be tested for the pictures you saw yesterday. You will see a mixture of "old" pictures (seen yesterday) and "new" pictures (not seen yesterday). Your task is to decide, for each picture, whether it is **Old** (previously seen) or **New** (previously unseen).



If you think the picture is "old" you will be asked to further decide whether you "remember" seeing the picture yesterday, or whether you simply "know" that you saw it yesterday. Below we explain in more detail the distinction between "remember" and "know" responses:

***Know judgments* (K)?**

"Know" responses should be made when you recognize the picture but it fails to evoke any specific conscious recollection.

For example: Picture may seem familiar, or may seem to just jump out at you, or you may think that it just seems right to you or you may just have this feeling of having encountered the item in the materials.

In other words, you "know" picture when you are certain of recognizing the picture but these pictures fail to evoke any specific conscious recollection from the pictures watched yesterday.

***Remember judgments* (R)?**

"Remember" is the ability to become consciously aware again of some aspect or aspects of what happened or what was experienced at the time the picture was presented

For Example: It might be aspects of physical appearance of the picture, something about its position in time (i.e., what came before or after the picture) or of what you were thinking at the time when picture was displayed, including any mental images you might have formed). In other words, the "remembered" picture should bring back to mind a particular association, another image, thought, feeling, or something more personal from the time of study, sound and

Appendix O

Debriefing sheet

Durham University – Department of Psychology

Thank you for your participation in our experiment.

This experiment investigates if your memory for emotional images is affected by anticipation of the emotional nature of the upcoming images.

We know that people remember emotional stimuli better than non-emotional stimuli. Is this because emotional stimuli are surprising and catch people off guard when compared to less surprising neutral stimuli? If so, this memory advantage of emotional stimuli should be reduced if we warn people about the nature of the stimuli they are going to see.

To test that, we compared memory performance in two conditions. In one condition, you were told about the nature of the upcoming image (negative vs. neutral); in the other condition, you were not told about the nature of the upcoming image. We are going to look at both (*i*) the behavioural data (whether memory performance is affected by information about the nature of the stimulus), (*ii*) the electrophysiological data (whether the electrical indices of memory are affected by information about the nature of the stimulus).

The results of this experiment can potentially help us better understand how emotional memories are formed and how pre-stimulus brain activity can affect this process. Ultimately, these results could contribute to better understanding the role of emotional memories in a range of mental health disorders, such as post-traumatic stress disorder.

We understand that some of the images used in the experiment have highly negative content. If viewing these images has caused you to feel distressed in any way, please contact the Durham University Counselling Service on 01913 340 039 or visit their website at www.dur.ac.uk/counselling.service

Thank you again, and if you have any questions feel free to contact me at any time.

Postgraduate Researcher:

Nazool-e Tabassum
Wolfson Research Institute
University of Durham,
Queen's Campus
Stockton-on-Tees
TS17 6BH, UK

nazool.tabassum@durham.ac.uk

Post-doctoral Researcher:

Luciano Buratto, PhD
Wolfson Research Institute
University of Durham,
Queen's Campus
Stockton-on-Tees
TS17 6BH, UK

luciano.buratto@durham.ac.uk

Principal Investigator:
Alexandre Schaefer, PhD
Wolfson Research Institute
University of Durham,
Queen's Campus
Stockton-on-Tees
TS17 6BH, UK

alexandre.schaefer@durham.ac.uk

Appendix P

Result information request form

Durham University – Department of Psychology

Result information request form

I would like to receive information about the results and/or publications stemming from this research.

Project Name	Anticipation and Emotional memory (EEG)
Participant Name	
Contact Information	

By signing and dating this form you request that we contact you with information about the results from the project indicated above using the contact information indicated above.

Signature: ______________________________

Date: __________________________________

Appendix Q

List of high arousal emotionally negative and neutral images selected from The Geneva Affective Picture database (GAPED: Dan-Glauser & Scherer, 2011)

List of Negative Pictures				List of Neutral Pictures			
#	Picture Nos.	Valence	Arousal	#	Picture Nos.	Valence	Arousal
1	H092.jpg	15.491	65.453	1	N001.jpg	57.245	17.909
2	H003.jpg	22.991	64.583	2	N002.jpg	55.043	41.503
3	H005.jpg	2.377	72.751	3	N003.jpg	54.109	30.974
4	H008.jpg	26.711	61.011	4	N004.jpg	40.953	40.422
5	H019.jpg	22.394	70.389	5	N006.jpg	53.835	37.388
6	H022.jpg	0.72	92.402	6	N008.jpg	59.745	22.977
7	H026.jpg	12.776	73.275	7	N009.jpg	62.174	15.005
8	H030.jpg	11.803	75.193	8	N010.jpg	60.196	12.907
9	H032.jpg	1.929	77.861	9	N011.jpg	49.069	29.336
10	H034.jpg	6.758	78.315	10	N013.jpg	61.967	10.196
11	H035.jpg	19.757	66.382	11	N014.jpg	59.275	14.34
12	H036.jpg	9.221	83.398	12	N015.jpg	54.05	29.756
13	H037.jpg	8.019	82.656	13	N017.jpg	68.63	14.291
14	H038.jpg	1.789	71.26	14	N018.jpg	59.426	20.317
15	H041.jpg	13.962	72.308	15	N019.jpg	61.12	27.267
16	H048.jpg	15.751	68.614	16	N020.jpg	51.299	26.213
17	H053.jpg	29.308	62.445	17	N021.jpg	57.788	29.029
18	H055.jpg	34.008	60.451	18	N022.jpg	57.851	22.96
19	H056.jpg	2.615	68.525	19	N023.jpg	68.85	29.736
20	H062.jpg	14.063	66.984	20	N024.jpg	56.168	16.541
21	H063.jpg	5.666	81.855	21	N025.jpg	51.873	23.84
22	H064.jpg	8.839	80.739	22	N026.jpg	43.063	20.506
23	H065.jpg	16.598	68.414	23	N027.jpg	60.927	26.823
24	H066.jpg	4.016	80.577	24	N028.jpg	67.042	20.103
25	H074.jpg	2.022	87.282	25	N031.jpg	51.964	20.868
26	H077.jpg	0.779	91.29	26	N032.jpg	54.083	21.452
27	H078.jpg	7.931	74.38	27	N033.jpg	48.306	26.599
28	H079.jpg	3.442	71.13	28	N034.jpg	55.883	16.563
29	H081.jpg	10.475	77.612	29	N035.jpg	54.51	18.36
30	H082.jpg	17.722	65.068	30	N036.jpg	52.852	18.706
31	H083.jpg	24.468	68.306	31	N037.jpg	53.38	19.829
32	H084.jpg	18.429	82.425	32	N038.jpg	61.954	31.339
33	H087.jpg	10.788	75.598	33	N039.jpg	49.431	17.885
34	H093.jpg	17.284	68.604	34	N040.jpg	54.189	29.566
35	H099.jpg	10.942	68.792	35	N041.jpg	54.996	24.654
36	H100.jpg	5.095	60.461	36	N042.jpg	67.751	21.501
37	H104.jpg	13.382	73.529	37	N044.jpg	61.87	31.986

38	H105.jpg	5.232	76.05	38	N045.jpg	53.572	14.802
39	H112.jpg	17.421	79.824	39	N046.jpg	47.496	26.05
40	H122.jpg	3.675	83.936	40	N047.jpg	53.307	27.769
41	H123.jpg	9.926	77.079	41	N061.jpg	49.541	10.674
42	H124.jpg	9.987	70.588	42	N062.jpg	55.356	29.713
43	H125.jpg	34.254	61.699	43	N064.jpg	45.527	25.069
44	H011.jpg	15.989	68.184	44	N065.jpg	65.689	20.149
45	H039.jpg	39.06	59.507	45	N066.jpg	63.756	43.122
46	H097.jpg	25.612	57.728	46	N067.jpg	45.176	23.793
47	H108.jpg	35.272	57.281	47	N068.jpg	58.674	16.423
48	A001.jpg	2.553	74.995	48	N069.jpg	65.852	32.872
49	A007.jpg	9.945	80.94	49	N071.jpg	55.113	43.792
50	A008.jpg	13.941	61.118	50	N072.jpg	51.181	17.69
51	A011.jpg	15.314	65.202	51	N073.jpg	47.181	29.76
52	A013.jpg	2.116	71.199	52	N075.jpg	44.451	41.667
53	A014.jpg	13.449	68.205	53	N076.jpg	57.156	18.505
54	A018.jpg	2.951	80.254	54	N077.jpg	67.722	29.926
55	A021.jpg	11.466	73.033	55	N078.jpg	53.441	27.879
56	A025.jpg	12.698	70.391	56	N079.jpg	53.551	18.336
57	A030.jpg	3.492	74.032	57	N080.jpg	59.67	20.826
58	A033.jpg	11.406	75.875	58	N081.jpg	50.247	23.782
59	A036.jpg	10.099	69.008	59	N082.jpg	62.644	37.583
60	A040.jpg	13.283	63.131	60	N083.jpg	53.876	29.436
61	A041.jpg	1.354	83.041	61	N086.jpg	62.29	36.256
62	A042.jpg	15.551	66.332	62	N087.jpg	48.873	30.279
63	A048.jpg	20.067	67.133	63	N088.jpg	58.806	23.673
64	A049.jpg	20.805	63.986	64	N089.jpg	50.168	13.26
65	A050.jpg	17.095	74.867	65	N090.jpg	62.827	25.464
66	A054.jpg	31.094	65.351	66	N091.jpg	53.994	12.065
67	A055.jpg	9.603	78.258	67	N092.jpg	49.675	21.311
68	A058.jpg	23.977	62.866	68	N093.jpg	56.704	23.687
69	A062.jpg	13.92	67.251	69	N094.jpg	51.367	23.246
70	A064.jpg	34.857	61.277	70	N095.jpg	57.445	22.96
71	A068.jpg	11.99	71.169	71	N096.jpg	55.886	35.069
72	A069.jpg	15.834	63.027	72	N097.jpg	52.912	22.261
73	A070.jpg	15.536	66.856	73	N099.jpg	59.797	43.108
74	A071.jpg	5.957	68.24	74	N100.jpg	61.645	30.254
75	A072.jpg	24.545	62.188	75	N101.jpg	50.112	18.488
76	A073.jpg	11.092	63.592	76	N102.jpg	46.393	26.089
77	A075.jpg	0.414	89.04	77	N104.jpg	57.932	32.797
78	A076.jpg	18.368	60.1	78	N105.jpg	61.819	25.901
79	A079.jpg	7.469	70.881	79	N106.jpg	51.211	23.401
80	A083.jpg	7.076	82.561	80	N107.jpg	52.177	31.665
81	A084.jpg	21.07	63.252	81	N108.jpg	60.457	13.713
82	A087.jpg	16.036	63.062	82	N109.jpg	50.609	21.657
83	A089.jpg	3.07	83.622	83	N111.jpg	50.872	20.61
84	A091.jpg	10.828	75.485				

85	A095.jpg	6.366	74.934				
86	A097.jpg	8.238	74.02				
87	A099.jpg	10.28	67.766				
88	A100.jpg	1.723	82.476				
89	A104.jpg	10.215	63.457				
90	A115.jpg	16.12	74.747				
91	A116.jpg	10.928	72.923				
92	A117.jpg	11.872	62.752				
93	A118.jpg	25.933	62.276				
94	A120.jpg	12.011	71.41				
95	A123.jpg	22.219	61.983				
96	A125.jpg	10.435	73.231				
97	A131.jpg	13.615	62.057				
98	A010.jpg	20.095	59.918				
99	A027.jpg	14.332	59.137				
100	A056.jpg	17.083	59.645				
101	A098.jpg	17.543	58.951				
102	A119.jpg	18.398	67.636				
103	A128.jpg	14.139	76.389				
104	Sp034.jpg	35.625	55.613				
105	Sp152.jpg	32.774	61.638				
106	Sp153.jpg	11.817	74.541				
107	Sn068.jpg	45.437	67.818				
108	Sn078.jpg	41.842	61.258				
109	Sn102.jpg	41.817	72.416				
110	Sn113.jpg	45.101	44.814				

Appendix R

Eqn	Ans	Answer	Eqn	Ans	Answer	Eqn	Ans	Answer
(3+7-4)=7	2	n	(60/15)=5	2	n	(13+14-24)=4	2	n
(4+7-3)=8	1	y	(117/13)=9	1	y	(15+11-25)=1	1	y
(1+5-2)=3	2	n	(152/19)=7	2	n	(12+16-19)=8	2	n
(4+2-1)=5	1	y	(99/11)=9	1	y	(19+19-35)=3	1	y
(5+6-3)=9	2	n	(30/15)=3	2	n	(19+18-36)=2	2	n
(4+8-6)=6	1	y	(112/14)=8	1	y	(17+12-23)=6	1	y
(5+8-6)=6	2	n	(48/16)=2	2	n	(12+12-22)=1	2	n
(8+3-8)=3	1	y	(90/18)=5	1	y	(15+12-22)=5	1	y
(7+4-5)=7	2	n	(68/17)=5	2	n	(16+14-26)=5	2	n
(2+3-2)=3	1	y	(128/16)=8	1	y	(16+15-27)=4	1	y
(3+7-4)=5	2	n	(36/18)=1	2	n	(15+12-22)=4	2	n
(5+2-1)=6	1	y	(48/12)=4	1	y	(14+11-24)=1	1	y
(5+7-4)=9	2	n	(72/18)=5	2	n	(15+17-28)=5	2	n
(1+8-5)=4	1	y	(84/14)=6	1	y	(16+18-27)=7	1	y
(8+4-9)=2	2	n	(38/19)=1	2	n	(12+15-20)=6	2	n
(7+4-8)=3	1	y	(60/12)=5	1	y	(15+11-22)=4	1	y
(7+8-6)=8	2	n	(126/14)=8	2	n	(16+13-24)=6	2	n
(2+4-5)=1	1	y	(60/12)=5	1	y	(19+12-30)=1	1	y
(7+3-9)=2	2	n	(153/17)=8	2	n	(13+18-26)=4	2	n
(5+7-4)=8	1	y	(112/16)=7	1	y	(14+11-21)=4	1	y
(2+6-4)=5	2	n	(39/13)=4	2	n	(14+16-27)=4	2	n
(3+5-1)=7	1	y	(144/18)=8	1	y	(18+11-27)=2	1	y
(1+2-1)=1	2	n	(51/17)=2	2	n	(11+15-20)=5	2	n
(4+8-6)=6	1	y	(84/14)=6	1	y	(18+11-21)=8	1	y
(7+1-2)=7	2	n	(38/19)=3	2	n	(13+18-24)=8	2	n
(8+2-6)=4	1	y	(33/11)=3	1	y	(18+12-21)=9	1	y
(7+4-2)=8	2	n	(78/13)=5	2	n	(13+17-21)=8	2	n
(5+4-2)=7	1	y	(22/11)=2	1	y	(18+11-21)=8	1	y
(2+9-10)=2	2	n	(85/17)=6	2	n	(15+17-26)=7	2	n
(5+4-8)=1	1	y	(26/13)=2	1	y	(17+15-24)=8	1	y
(2+6-7)=2	2	n	(56/14)=3	2	n	(16+13-24)=4	2	n
(9+1-1)=9	1	y	(84/14)=6	1	y	(16+14-24)=6	1	y
(5+7-3)=8	2	n	(114/19)=7	2	n	(16+12-25)=4	2	n
(6+6-7)=5	1	y	(65/13)=5	1	y	(18+11-26)=3	1	y
(7+3-4)=5	2	n	(120/15)=7	2	n	(11+11-19)=2	2	n
(7+5-4)=8	1	y	(39/13)=3	1	y	(16+15-26)=5	1	y
(1+8-2)=8	2	n	(120/15)=9	2	n	(15+19-33)=2	2	n
(4+9-6)=7	1	y	(104/13)=8	1	y	(17+14-29)=2	1	y
(8+6-12)=1	2	n	(152/19)=7	2	n	(19+18-33)=3	2	n

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